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THE PREPARATION AND PHYSICAL PROPERTIES OF PLASTER BOARD FROM SUGAR CANE BAGASSE [1]

PASCUAL T. TANTENGCO, JR.[2]

Successive one-day treatments with aqueous solutions of one per cent H_2SO_4 and 18 per cent NaOH at room temperature and atmospheric pressure were found sufficient to prepare the bagasse for molding. Higher concentrations of the reagents used and longer processing periods did not increase the recovery of fibers nor improve the quality of the resulting board.

The physical properties of the plaster board varied significantly between molding treatments and kind of bagasse used. Treatment means showed that bagasse treated with 60 per cent Plaskon (urea-formaldehyde resin) for 30 minutes at 150°C (327.6°F) and 5,000 pounds per square inch pressure gave the highest tensile strength and shearing stress. Unground bagasse gave products with higher tensile strength and shearing stress than ground bagasse. Ground bagasse, however, gave much finer texture and higher surface gloss than unground bagasse.

Bagasse is one of the by-products of the sugar industry. In Japan, United States and other industrial countries, studies on bagasse have opened new fields in the sugar industry, such as the manufacture of paper boards, chemicals and plastics. Its use in the manufacture of artificial silk (rayon) was reported by Valenzuela and West in 1930.[3] In India, Varma and Sinha [4] indicated its successful use in the manufacture of pulp for rayon, cellophane, capsules and other viscose products.

In the Philippines, only a few studies have been conducted on the utilization of this by-product as a raw material for industry. Millions of tons of bagasse produced annually are regarded as waste and generally used as fuel.

The object of this study was to investigate some methods of preparing plastic materials from bagasse and to evaluate their phys-

[1] Central Experiment Station Contribution No. 1988. Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, October, 1957. Prepared in the Department of Agricultural Chemistry under the direction of Associate Professor Leopoldo J. Villanueva.

[2] The author is grateful to the Canlubang Sugar Central for furnishing the bagasse and to the Santa Clara Lumber Company for furnishing the resin.

[3] A. Valenzuela and A. West, *Phil. Jour. of Sci. 40*, 275-281 (1930).

[4] P. S. Varma and A. Sinha, *Proc. Nat'l Acad. Sci. India 20A*, 11-28 (1951).

ical properties. The work was conducted in the Department of Agricultural Chemistry from July, 1956, to October, 1957.

MATERIALS AND METHODS

Processing of the bagasse. Twenty-five 200-gram samples of ground [5] and unground bagasse were weighed in separate 600-milliliter beakers. These were equally divided into five lots, and each lot was further divided into five sublots. Five different dilute solutions of H_2SO_4 and NaOH were prepared for the digestion of bagasse. The samples were treated with the acid solution and after each acid treatment, washed and hand-pressed. They were subsequently treated with dilute NaOH solutions and washed free of the alkali. Water was pressed out with the Carver laboratory press at 15,000 pounds per square inch (p.s.i.) pressure. The samples were air-dried, re-weighed to determine percentage recovery, and oven-dried in the Fisher forced-draft isotemp oven at 125° to 130C° to an approximately 13 to 15 per cent moisture content. The samples were then kept in desiccators.

Acid and alkali treatments were done at different lengths of time at room temperature and atmospheric pressure as follows:

LOT	SUBLOT Bagasse		TREATMENT	
	Unground	Ground	H_2SO_4 per cent	NaOH per cent
	1A	1B	1.0	18
	2A	2B	1.5	20
I	3A	3B	2.0	22
(1 day)	4A	4B	2.5	24
	5A	5B	3.0	26
	1A	1B	1.0	18
	2A	2B	1.5	20
II	3A	3B	2.0	22
(2 days)	4A	4B	2.5	24
	5A	5B	3.0	26
	1A	1B	1.0	18
	2A	2B	1.5	20
III	3A	3B	2.0	22
(3 days)	4A	4B	2.5	24
	5A	5B	3.0	26
	1A	1B	1.0	18
	2A	2B	1.5	20
IV	3A	3B	2.0	22
(4 days)	4A	4B	2.5	24
	5A	5B	3.0	26

[5] Ground in a Wiley grinder to pass 100 mesh.

	1A	1B	1.0	18
	2A	2B	1.5	20
V	3A	3B	2.0	22
(5 days)	4A	4B	2.5	24
	5A	5B	3.0	26

Formation of plastic material. Two-gram samples from each sublot were used as the base material for the plastic product. Urea-formaldehyde resin was mixed thoroughly with the bagasse in a beaker and the mixture was molded and pressed.

The variables in this phase of the experiment were:

1. Amount of resin mixed (per cent by weight)
2. Temperature of curing [6]
3. Length of time for curing
4. Pressure

The following treatments were made:

I. 35% resin—(100°C)—5,000 p.s.i. for 15 min.
II. 50% resin—(100°C)—5,000 p.s.i. for 15 min.
III. 60% resin—(100°C)—5,000 p.s.i. for 15 min.
IV. 35% resin—(100°C)—5,000 p.s.i. for 15 min.
V. 50% resin—(100°C)—5,000 p.s.i. for 30 min.
VI. 60% resin—(100°C)—5,000 p.s.i. for 30 min.
VII. 35% resin—(100°C)—5,000 p.s.i. for 30 min.
VIII. 50% resin—(100°C)—5,000 p.s.i. for 45 min.
IX. 60% resin—(100°C)—5,000 p.s.i. for 45 min.
X. 50% resin—(130°C)—5,000 p.s.i. for 30 min.
XI. 50% resin—(140°C)—5,000 p.s.i. for 30 min.
XII. 50% resin—(150°C)—5,000 p.s.i. for 30 min.
XIII. 50% resin—(140°C)—7,000 p.s.i. for 30 min.
XIV. 50% resin—(140°C)—10,000 p.s.i. for 30 min.

All of the foregoing treatments were applied to each of the sublots in every lot.

In the preliminary trials, the 50 per cent resin and 30-minute runs gave the best results. This basis was employed to justify the use of the 50 per cent and 30-minute treatments in subsequent runs where pressure and temperature were increased.

[6] Temperature of the electric plates was regulated by means of Fenwal Thermoswitch.

The finished products were subjected to different physical tests:

Tensile strength. The finished samples were cut into one-inch-wide strips. The cross-sectional dimension was taken with a micrometer. Scott Tester Model J2 was used to determine the breaking load of the samples. To compute the tensile strength, the following formula was used:

$$\text{Tensile strength} = \frac{\text{Breaking load}}{\text{cross-sectional area}}$$

For uniformity of units, all kilogram measurements of the breaking loads were converted into pounds.

Shearing stress. For determining the shearing stress, the Scott Tester Model J2 for tensile strength was also used as there was no available machine for the sample size. However, the plastic strips were uniformly cut to suit the purpose. Results were expressed in kilograms per square centimeter. The following formula was used:

$$\text{Shearing stress} = \frac{\text{maximum shearing load (kg.)}}{\text{area (sq. cm.)}}$$

Soaking properties. To determine the water absorption property of the product, weighed samples were soaked in water for 24 hours, hand-pressed, wiped dry with absorbent paper and re-weighed. The amount of water absorbed was calculated as follows:

$$\%\ H_2O = \frac{\text{weight of water absorbed} \times 100}{\text{weight of sample}}$$

Other physical properties such as color, odor, luster, and texture were evaluated from the general appearance of the finished product.

RESULTS AND DISCUSSION

Processing of bagasse. The recovery of bagasse fibers from the original weight after subsequent acid and alkali treatments did not differ significantly between treatments or between lengths of time of treatments. An average recovery of 50.16 per cent was obtained. No further appreciable decrease in recovery was obtained after the one-day treatment. This indicates that digestion was completed after one day at room temperature and atmospheric pressure.

Tensile srength. Analysis showed that the tensile strength of the plastic products varied significantly between treatments (table 1). In treatments I to IX, where temperature and pressure were

TABLE 1.—*Tensile strength (lbs./sq. in.) of plastic materials from bagasse*

	TREATMENT	MEAN	MATERIAL	MEAN
	I	1,422.9	A	1,693.9
	II	1,461.2	B	1,404.5
	III	1,460.5		
	IV	1,410.9		
	V	1,637.7		
	VI	1,643.7		
	VII	1,423.3		
	VIII	1,618.7		
	IX	1,624.4		
	X	1,652.0		
	XI	1,654.1		
	XII	1,664.7		
	XIII	1,494.3		
	XIV	1,480.0		
HSD	.05	42.70		32.36
	.01	53.09		45.05

not changed and where only the length of time of curing and the amount of resin mixed were varied, all the samples run for 30 minutes with 60 per cent resin gave the best results. An average tensile strength of 1,643.7 p.s.i. was obtained. This was followed by the samples run for 30 minutes with 50 per cent resin which gave an average tensile strength of 1,637.7 pounds per square inch. In treatments I to IX, the thickness of the samples ranged from 0.053 to 0.056 inch (table 2).

When the temperature was increased (treatments X to XII) the tensile strength of the samples increased significantly. An average tensile strength of 1,664.7 p.s.i. was obtained from treatment XII (50 per cent resin—150°C—5,000 lbs./sq. in. pressure—30 min.). This treatment gave the best results. The thickness of the materials in this treatment had an average of 0.053 inch.

TABLE 2.—*Ranges and averages of thickness and breaking loads of materials in tensile strength determination*

TREATMENT	THICKNESS (INCH)	BREAKING LOAD (POUNDS)
	Average	Average
I	0.053	75.1
II	0.054	76.5
III	0.053	79.7
IV	0.054	71.7
V	0.054	88.3
VI	0.056	91.7
VII	0.054	77.4
VIII	0.054	95.6
IX	0.053	86.0
X	0.053	88.3
XI	0.053	88.4
XII	0.053	88.1
XIII	0.043	64.9
XIV	0.032	48.6

Increasing the pressure decreased the tensile strength of the products from both ground and unground bagasse. A decrease in the thickness of the samples was also obtained.

In all determinations made, unground bagasse gave better results than ground bagasse. In treatment XII, the highest tensile strength obtained from unground bagasse was 1,831.6 p.s.i. whereas that from ground bagasse, 1,499.9 pounds per square inch. This may have been due to the interlinking of the fibers in the unground bagasse.

Longer digestion periods in the preparation of bagasse, and various concentrations of acid and alkali used did not give any significant increase or decrease in the tensile strength of the finished product from both ground and unground bagasse.

Shearing stress. In the shearing stress determinations all treatments varied significantly from each other (table 3). In treatments I to IX where the pressure was 5,773 kg./sq. cm. (5,000 p.s.i.) and the temperature 100°C (237.6°F) and where only the amount of resin added and the length of time for curing were varied, all 45-minute runs with 60 per cent resin gave the best results, with an average shearing stress of 18.3 kilograms per square centimeter for samples from unground bagasse and 14.9 kilograms per square centi-

TABLE 3.—*Shearing stress (in kgm./sq. cm.) of plastic materials from bagasse*

TREATMENT	MEAN	MATERIAL	MEAN
I	14.5	A	16.7
II	14.5	B	14.9
III	16.0		
IV	15.2		
V	15.7		
VI	16.1		
VII	15.4		
VIII	16.5		
IX	16.7		
X	16.4		
XI	16.2		
XII	16.7		
XIII	16.2		
XIV	14.9		
HSD			
.05	0.56		0.48
.01	0.45		0.35

meter for samples from ground bagasse, or a treatment over-all average of 16.7 kilograms per square centimeter. This was closely followed by 45-minute runs with 50 per cent resin. In this treatment an average shearing stress of 18.0 kilograms per square centimeter from unground bagasse and 14.8 kilograms per square centimeter from ground bagasse were obtained. The average in this treatment for the two materials was 16.5 kilograms per square centimeter.

Increasing the temperature also increased the shearing stress of the samples, especially with ground bagasse. Treatment XII (50 per cent resin—140°C (309.6°F)—5,337.42 kg./sq. cm. (5,000 p.s.i. for 30 min.) gave the best result An average of 16.7 kilograms per square centimeter was obtained for both ground and unground bagasse. Although treatment IX gave the same average shearing stress as treatment XII, the latter was still considered the best since the amount of resin added was less and the length of time for curing was shorter.

Increasing the pressure decreased the shearing stress of the finished product. At 10,675 kg./sq. cm. (10,000 p.s.i.) pressure (treatment XIV), the average shearing stress of the samples was only 14.9 kilograms per square centimeter.

In all determinations, unground bagasse gave higher shearing stress than ground bagasse. Again, this difference may be attributed to the interlinking of the fibers in unground bagasse.

Neither the various concentrations of acid and alkali used nor the length of digestion period affected the shearing stress of the finished product.

Soaking property. All the samples increased in weight after having been soaked in water for 24 hours. This indicated that not one of the treatments made the products water-resistant. The amount of water absorbed varied significantly between treatments and with the nature of the bagasse (table 4). Water absorption

TABLE 4.—*Water absorption (in per cent) of plastic materials from bagasse*

	TREATMENT	MEAN	MATERIAL	MEAN
	I	23.4	A	20.3
	II	22.9	B	21.3
	III	21.9		
	IV	23.2		
	V	21.2		
	VI	20.8		
	VII	22.9		
	VIII	20.0		
	IX	20.6		
	X	20.6		
	XI	20.66		
	XII	20.1		
	XIII	18.7		
	XIV	18.1		
HSD				
.05		0.50		0.38
.01		0.62		0.52

ranged from 16.1 to 22.7 per cent for samples from unground bagasse and 19.4 to 24.7 per cent for samples from ground bagasse.

When the pressure was increased, water absorption also decreased. The least amount of water absorbed was obtained from treatment XIV where the pressure applied was 10.675 kg. per sq. cm. (10,000 p.s.i.). This treatment gave an average of 16.4 per cent for samples with ground bagasse. This decrease in water absorption may be attributed to the relative high pressure which is

believed to have rendered the materials more compact, thereby narrowing the water interstices. In all treatments ground bagasse gave better results than unground bagasse.

Increasing the amount of resin and lengthening the time of curing decreased the water-absorbing property of the materials. At 5,337.4 kg./sq. cm. (5,000 p.s.i.) pressure and 100°C (237.6°F), all the samples with 50 per cent resin and run for 15 minutes had higher water absorption than any other treatment with the same pressure and temperature. An average of 22.9 per cent was obtained from this particular treatment. When the temperature and the time of curing were increased an appreciable decrease in water absorption was obtained. At 140°C (309.6°F) samples from unground bagasse gave an average of 16.4 per cent and those from ground bagasse gave 19.6 per cent (treatment XIV, table 4).

Again the length of the digestion period and the various concentrations of the reagents did not have any effect on the soaking property of the plastic products (plaster board).

Other properties. Plastic materials obtained from ground bagasse were finer, much darker brown and more shiny than unground bagasse. With regard to odor, no distinction could be made between treatments or between the materials used. All retained the odor of the formaldehyde.

* * *

"The ideal of a university is not so much knowledge as power. Its business is to convert the knowledge of a boy into the power of a man."

—*A. N. Whitehead*

ESTIMATING RICE PRODUCTION BY USING THREE SAMPLING UNITS [1]

MARIANO B. DE RAMOS

In stratified random sampling, the proportional-to-size-and-variance method of allocation of sizes gave the smallest variance. The variance of the different sampling schemes decreased as sample size increased. Of the sampling schemes, geographic stratification was the most efficient and systematic stratification was the least efficient.

The underestimation of interview yield was 1.41 cavans per hectare. All estimated yields of the different shapes of plots exceeded the actual yield. There were insignificant differences in the yield of the three plots.

Reliable estimates of annual production of rice in the Philippines are becoming extremely important as the country makes serious efforts to tackle the problem of food self-sufficiency. Direct measurement of total rice production with any degree of reliability is not possible because this crop is grown by almost all farmers of the country, the greater percentage of whom do not keep accountings and records, and are generally reluctant to give information.

The method of yield estimation practised at present is purely subjective. In order to have a more or less accurate estimate, objective methods should be used. One of these methods is the use of sampling designs and surveys particularly crop cutting.

Estimation of yield by crop cutting involves the selection of a representative sample of a crop over the area which is being studied and the harvesting and weighing of the produce from each of the several units constituting the sample. The sampling units are plots of prescribed dimensions randomly selected from the field. Since rice fields are of different kinds, e.g., irrigated, fertilized or growing improved variety, the field is divided into strata to increase the efficiency of the sampling method.

Crop cutting is practicable and gives unbiased and very accurate estimates. The method has been demonstrated by several large-

[1] Central Experiment Station Contribution No. 1989. Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, June, 1956. Prepared in the Department of Agricultural Engineering under the direction of Assistant Professor Burton T. Oñate and Mr. Amador D. Yñiguez.

scale crop-cutting surveys in different countries like India, England, and the United States.

The most extensive investigations on this subject were conducted in India where the relative efficiency of different plot sizes was tested. The results showed that the smallest triangle and the two circular plots gave serious overestimation of yield.

Yates, as cited by Sukhatme (1946), reported biased results from the use of small-sized plots. Yates said that overestimation appeared to be due to the harvesters' tendency to include border plants outside the plots. These reports were confirmed by Sukhatme when he conducted a similar investigation on wheat. Sampling units of 12.5 sq. ft. resulted in biased estimates of yield.

Sukhatme (1946) found in studying the bias in the use of small-sized plots in sample surveys for yield of cotton, wheat, and paddy that there was a serious overestimation of yield in plots less than 30 sq. ft. He further observed that the bias diminished with an increase in the size of plot, but even plots of 118 sq. ft. were not free from bias.

The problem of plot size in large-scale yield surveys was studied again in India recently. Plot sizes of 1/10th, 1/40th, 1/160th, and 1/800th of an acre were used. In contrast, workers in England, the United States, and India have used very small plot sizes. Thus Cochran (1940) in England used a plot size six rows wide and a quarter of a meter long. In India, a small-sized plot of 13.6 sq. ft. was first used by Mahalanobis (1945).

These studies showed that there was a definite risk of obtaining overestimates of the average yield with small-sized plots. In contrast, Sukhatme (1947) reported that plots measuring 1/80th of an acre appeared to be free from bias and that small plots failed to furnish unbiased estimates of the different components of the true variance.

This study was conducted from April, 1955, to April, 1956, in the barrio of Bubucal, Sta. Maria, Laguna, and in the Department of Agricultural Engineering, College of Agriculture, to determine (1) the relative efficiencies of different sampling schemes, (2) the percentage of overestimation or underestimation of interview method, (3) bias of the different shapes, and (4) variances of the different sampling units.

MATERIALS AND METHODS

A preliminary survey of the barrio of Bubucal, Sta. Maria, Laguna, was conducted in April, 1955, to determine the number of lowland rice fields, the total number of paddies in each field, the actual hectarage, and other pertinent data, such as the amount of seeds used per hectare, the methods of culture, variety of rice, and methods of harvesting and threshing.

Thirty-six lowland rice fields operated by the farmers residing in the barrio were used as the sampling area.

The sampling units or plots were in three shapes: square, triangle, and rectangle. Abacá twine, tied to steel pegs, served as the borders of the 2-sq. m. plots.

Stratification. Four stratifications were made based on the following:

1. Geographic—The 36 lowland rice fields were divided into three divisions called strata. The first stratum consisted of ten farms on the eastern border of the barrio. It had a high elevation and insufficient irrigation. The second stratum consisted also of ten farms, but it had a lower elevation than the first stratum and sufficient irrigation. The third stratum had the most uniform topography and the most sufficient irrigation system because aside from the water coming from the nearby river which was the principal source of irrigation for the first two strata, a spring near the center made it possible to have a more or less controlled water supply in this area.

2. Average yield—The 36 lowland rice fields were divided into three strata based on the average interview yield per hectare. The first stratum consisted of the first twelve farms with the lowest average yield; the second stratum, the next twelve farms; and the third, the last twelve farms with the highest average yield.

3. Seeds per hectare—The stratification was the same as that of the average yield, except that seeds were in gantas per hectare.

4. Systematic—Starting from the southern border of the barrio, the 36 lowland rice fields were divided into three system numbers with twelve strata each. The first system number consisted of the first twelve farms; the second, the next twelve farms; and the third, the last twelve farms. Another stratification of two system numbers with 18 strata each was also used.

Sampling schemes. Four fields from each stratum were selected at random for sampling. Within three fields, two paddies were also selected at random, and in each paddy, six plots, two of each shape, were located by the coordinate system. These locations of plots were made two or three days before harvesting the whole field during February and March.

Harvesting and processing of samples. Throughout the harvesting period, the plants inside the plots were cut close to the ground, bundled separately, and labeled properly.

The panicles of each sample were separated from the straws and put into bags properly labeled. The straws of each sample were dried under the sun and their corresponding weights were recorded. Four representative plants without panicles from each sample were picked at random and their heights were also recorded. After a day's exposure under the sun, the panicles were threshed and the good grains of each sample were weighed and recorded. The moisture content of the grains of each sample was determined by a moisture tester just after weighing. The weights of the good grains of each sample were then standardized at 14 per cent moisture.

Harvesting and threshing. The methods of harvesting and threshing used by the farmers were observed to find out whether the overestimation of yields in crop cutting could be attributed to the loss due to carelessness in these operations. The actual yields of the twelve farms that were sampled were observed at the time of sharing.

Efficiencies of sampling schemes. Several sampling schemes were tried and variances were computed for each method using the formulas of Cochran (1953) which include:

1. Unrestricted random sampling:

$$V(\bar{x}) = \frac{S^2}{n}\frac{(N-n)}{N}$$

where $V(\bar{x})$ = variance of a sample mean
N = total number of farms
n = number of farm samples

$$S^2 = \sum_{i=1}^{N} \frac{(X_i - \mu)^2}{N-1}$$

S^2 = population variance (by definition)

$$\mu = \sum_{i=1}^{N} \frac{X_i}{N} \text{ population mean}$$

$$\bar{x} = \sum_{i=1}^{n} \frac{X_i}{n} \text{ sample mean}$$

2. Stratified random sampling:

2.1. Equal-sample-size:

$$n_i = n/3$$

$$V(\bar{\gamma}) = \sum_{i=1}^{3} (N_i/N)^2 (N_i - n_i/N_i) S_i^2/n_i$$

where N_i = number of units in ith stratum
n_i = number of sampling units in ith stratum
n = size of sample
S_i^2 = variance of ith stratum

2.2. Proportional-to-size:

$$n_i = nN_i/N$$

$$V(\bar{x}) = N - n/Nn \sum_{i=1}^{3} (n_i/n) S_i^2$$

2.3. Proportional-to-size-and-variance:

$$n_i = nN_iS_i / \sum_{i=1}^{n} N_iS_i$$

$$V(\bar{x}) = \sum_{i=1}^{3} (N_i/N)^2 [(N_i - n_i) N_i] S_i^2/n_i$$

The same formulas were used in the computations of sizes and variances for average yield and seeds per hectare in each sampling scheme.

3. Systematic random sampling:

$$V(\bar{x}) = \sum_{i=1}^{ni} (x_i - \mu)^2/n_i$$

where $\bar{x} = \sum_{i=1}^{ni} X_i/n$, mean of systematic sample

Test of bias. Biases of the three shapes of plots were computed by comparing the yields of the different plots with the actual

yield on a 14 per cent standard moisture content. Comparison was also made between the actual yield and the yield taken by interview.

Estimation of variances. Estimates of the variances of the different plot shapes were obtained from the analyses of the completely randomized and randomized block designs.

RESULTS AND DISCUSSION

Sampling efficiency. A comparison of the variances of the different sampling schemes is an appropriate test of sampling efficiency. The principle is that the smaller the variance of a particular sampling scheme, the more efficient it is.

Table 1 shows the comparison of variances of unrestricted (without stratification) and stratified random samplings. In stratified random sampling, the proportional-to-size-and-variance method of

TABLE 1.—*Sizes of sample and variances*

TYPE OF SAMPLING	SAMPLE SIZE		
	12	15	18
1. Unrestricted random sampling:			
$V(\bar{x})$	37.48	26.23	18.74
2. Stratified random sampling:			
2.1. Geographic:			
2.1.1. Equal sample size:	4,4,4	5,5,5	6,6,6
$V(\bar{x})$	23.75	16.31	11.35
2.1.2. Proportional to size	3,3,6	4,4,7	5,5,8
$V(\bar{x})$	25.25	17.96	13.43
2.1.3. Proportional to size and variance:	2,6,4	3,7,5	3,9,6
$V(\bar{x})$	16.11	12.60	7.86
2.2. Average yield:			
2.2.1. Equal sample size:	4,4,4	5,5,5	6,6,6
$V(\bar{x})$	31.53	22.07	15.76
2.2.2. Proportional to size:	4,4,4	5,5,5	6,6,6
$V(\bar{x})$	31.53	22.07	15.76
2.2.3. Proportional to size and variance:	3,2,7	3,3,9	4,4,10
$V(\bar{x})$	22.03	14.15	9.15
2.3. Seeds per hectare:			
2.3.1. Equal sample size:	4,4,4	5,5,5	6,6,6
$V(\bar{x})$	33.58	23.50	16.78
2.3.2. Proportional to size:	4,4,4	5,5,5	6,6,6
$V(\bar{x})$	33.58	23.50	16.78
2.3.3. Proportional to size and variance:	3,6,3	3,8,4	4,9,5
$V(\bar{x})$	27.14	17.87	12.15

allocation of sizes gave the smallest variance with the use of a size-12 sample. The variances for the different stratifications were 16.11 for geographic, 22.03 for average yield, and 27.14 for seeds per hectare. The equal-sample-size and proportional-to-size methods gave variances as much as from 23.75 to 33.58. This shows that the proportional-to-size-and-variance method was more efficient than the other two.

The same table shows that geographic stratification gave the smallest variance, followed by the average yield. The third was the seeds-per-hectare and the last, the unrestricted random sampling. Of the three sampling schemes, therefore, the most efficient was the geographic and the most inefficient was the unrestricted. The variance of all the different sampling schemes decreased as sample size increased.

Systematic random scheme was also tried for two different numbers of system. Table 2a shows that the systematic samples and 12 strata had a variance of 111.74. The stratification with two systematic samples and 18 strata had a variance of 79.21, which was much smaller than that of the first system (table 2b). These variances were very much higher than those of other sampling schemes shown in table 1.

Systematic stratification was the simplest and easiest method to apply, but the high variance obtained showed that it was the most inefficient of all the schemes used in this study.

TABLE 2a.—*Systematic stratification of the interview yield of rough rice in cavans*

STRATUM NO.	SYSTEMATIC SAMPLE NUMBER			TOTAL	MEAN
	1	2	3		
1	42	58	42	142	47.3
2	38	45	64	147	49.0
3	50	39	150	239	79.7
4	56	26	27	109	36.3
5	52	39	53	144	48.0
6	35	38	26	99	33.0
7	40	41	43	124	41.3
8	52	34	80	166	55.3
9	28	32	94	154	51.3
10	32	97	70	199	66.3
11	18	63	86	167	55.7
12	62	18	51	131	43.7
Total	505	530	786	1821	
Mean	42.1	44.2	65.5	50.58	

Analysis of variance

SV	DF	SS	MS
Strata	11	5424.75	493.18
Within strata	24	18186.00	757.74
Total	35	23610.75	674.59

$$V(\bar{x}) = 111.74$$

TABLE 2b.—*Systematic stratification of the interview yield of rough rice in cavans*

STRATUM NO.	SYSTEMATIC SAMPLE NUMBER		TOTAL	MEAN
	1	2		
1	42	41	83	41.5
2	38	34	72	36.0
3	50	32	82	41.0
4	56	97	153	76.5
5	52	63	115	57.5
6	35	18	53	26.5
7	40	42	82	41.0
8	52	64	116	58.0
9	28	150	178	89.0
10	32	27	59	29.5
11	18	53	71	35.5
12	62	26	88	44.0
13	58	43	101	50.5
14	45	80	125	62.5
15	39	94	133	66.5
16	26	70	96	48.0
17	39	86	125	62.5
18	38	51	89	44.5
Total	750	1071	1821	
Mean	41.7	59.5	50.6	

Analysis of variance

SV	DF	SS	MS
Strata	17	9211.25	541.84
Within strata	18	14399.50	799.97
Total	35	23610.75	674.59

$$V(\bar{x}) = 79.21$$

Overestimation or underestimation of interview method. The underestimation of interview or subjective yield was 1.41 cavans per hectare (table 3). This figure when multiplied by 31 hectares which is the area of the 36 fields, gave a total magnitude of underestima-

tion of 43.71 cavans. The subjective method gave only the trend, which was, however, a good indication for this barrio.

TABLE 3.—*Hectarage and actual and interview yields of rough rice in cavans* [a]

FARM	HECTARAGE	ACTUAL	INTERVIEW	DIFFERENCE
1	0.8	51.8	51.0	0.8
2	0.6	38.0	43.0	–5.0
3	1.1	48.3	42.0	6.3
4	0.5	30.0	38.0	–8.0
5	1.4	97.0	94.0	3.0
6	0.4	31.0	27.0	4.0
7	2.3	160.1	150.0	10.1
8	1.0	63.1	63.0	0.1
9	1.3	92.6	97.0	–4.4
10	0.4	30.4	26.0	4.4
11	0.4	28.1	28.0	0.1
12	0.5	35.7	32.0	3.7
Total	10.7	706.1	691.0	15.1

[a] Over-estimation: 1.41 cavans per hectare.

Test of bias. The test of bias was made by comparing the yields obtained from the different shapes of plots with the actual yield based on the 12 sampled farms. Results showed that the different estimated yields of the three plots exceeded the actual yield. The overestimation was 69.91 for rectangle, 53.37 for square, and 53.07 for triangle, or, in terms of percentage, rectangle had 9.90, square 7.55, and triangle 7.52 (table 4). The degree of overestimation of the different shapes could not be attributed to the length of perimeter because the triangle which had the maximum perimeter turned out to be least biased.

TABLE 4.—*Estimated and actual yields of rough rice in cavans with percentage of overestimation for plots of different shapes*

SHAPE	SIZE IN SQ. M.	NO. OF PLOTS	ESTIMATED YIELD	ACTUAL YIELD	OVERESTIMATION OR (UNDERESTIMATION)	PER CENT OVERESTIMATION OR (UNDERESTIMATION) [a]
Rectangle	2	48	776.01	706.1	69.91	9.90
Square	2	48	759.47	706.1	53.37	7.55
Triangle	2	48	759.17	706.1	53.07	7.52

[a] Percentage of overestimation was based on actual yield.

Table 5 shows the estimated yield of each shape, combined yield, and actual yield of rough rice in cavans expanded to 36 farms with percentage of overestimation. Individual yield exceeded the actual

yield by 186.79 cavans, or 8.79 per cent. These results showed the magnitude of the increase in overestimation as the estimation was expanded.

TABLE 5.—*Estimated yield of each shape, combined and actual yield of rough rice in cavans of the barrio with percentage of overestimation*

SHAPE	INDIVIDUAL YIELD	COMBINED YIELD	ACTUAL YIELD	OVERESTIMATION		PER CENT [a]	
				Ind. yield	Comb. yield	Ind. yield	Comb. yield
Rectangle	2328.03	2304.65	2118.3	209.73	186.35	9.90	8.79
Square	2278.41	2304.65	2118.3	160.11	186.35	7.55	8.79
Triangle	2277.51	2304.65	2118.3	159.21	186.35	7.52	8.79

[a] Percentage of overestimation was based on actual yield.

The biases of the different shapes may be attributed to the fact that the plots were very small or to the inclusion of the border plants outside the plots. Another cause could be the loss in harvesting and threshing by the farmers, which was estimated to be bigger than the loss in harvesting and processing the samples.

Analysis of variance. Statistical analysis showed that there were significant differences in the yields of paddies (table 6). The significant mean difference was 103.07 grams at five per cent level and 137.46 grams at one per cent level. There were insignificant differences in the yields of the three plots. In other words, the mean yields of the different plots were the same and any differences were due to random fluctuation.

TABLE 6.—*Yield of rough rice of the three shapes of plots in grams*

PADDY NO.	SHAPE						MEAN	TOTAL
	Rectangle		Square		Triangle			
	a	b	a	b	a	b		
1	697.75	657.90	684.66	682.21	739.67	726.39	4188.58	698.09
2	661.15	749.71	699.62	676.89	744.39	738.00	4269.76	711.62
3	873.05	813.46	837.59	1097.46	754.87	1028.88	5400.31	900.05
4	1054.96	767.69	977.61	928.16	776.42	1000.01	5504.85	917.47
5	985.55	1002.69	745.09	735.02	608.19	730.38	4806.92	801.15
6	749.70	970.42	767.69	706.59	760.68	772.43	4727.61	787.93
7	679.94	593.59	706.32	751.57	663.44	628.07	4022.93	670.48
8	799.49	573.34	700.59	608.61	725.58	771.53	4179.14	96.52
9	766.12	699.36	678.23	716.32	791.51	626.65	4278.19	713.03
10	672.77	628.04	637.56	622.98	664.04	802.92	4028.31	671.38
11	798.59	938.73	881.46	901.08	841.12	779.67	5140.65	856.77
12	788.33	754.90	929.96	800.16	949.88	890.22	5113.45	852.24
13	840.23	768.16	791.42	922.93	718.96	772.34	4814.04	802.34

TABLE 6 (Continued)

PADDY NO.	SHAPE						MEAN	TOTAL
	Rectangle		Square		Triangle			
	a	b	a	b	a	b		
14	709.82	795.00	699.58	887.15	797.68	760.61	4649.94	774.99
15	809.54	763.58	730.03	786.80	838.37	823.12	4751.44	791.90
16	652.09	820.95	703.36	817.99	755.61	759.65	4509.65	751.60
17	860.33	988.90	975.85	820.38	743.53	787.54	5176.53	862.75
18	868.64	905.53	858.94	946.77	820.08	828.29	5228.45	871.41
19	764.16	875.86	816.66	949.34	898.81	1125.26	5430.09	905.01
20	1154.71	944.51	1001.64	778.15	911.32	1085.37	5875.70	979.28
21	859.54	816.12	810.29	928.91	657.49	959.24	5031.59	838.59
22	1033.60	950.42	849.83	997.54	846.98	751.44	5429.81	904.96
23	839.08	831.30	776.86	821.26	921.42	986.00	5176.01	862.66
24	785.45	932.26	895.05	968.03	967.76	759.22	5307.77	884.63
Total	39247.30		39008.19		38786.23			
Mean	817.65		812.67		808.04			

Analysis of variance

SV	DF	SS	MS	COMP. F	PROB.
Sampling error	72	611243.46	8489.49		
Paddy (P)	23	1047684.50	45551.50	5.76	<.01
Shape (S)	2	2215.50	1107.75	0.14	>.05
P × S	46	363760.80	7907.84	0.93	>.05
Total	143	2024904.26			

S.M.D. (P) at 5% = 103.07
S.M.D. (P) at 1% = 137.46

Within each shape of plot, except in the triangle, the differences in the yield of strata were all found to be highly significant (tables 7a, 7b, and 7c). There were also significant differences in the yield of farms within strata for the square and the triangle, but not for the rectangle. The differences in the yield of paddies were all insignificant for the three plot shapes.

TABLE 7.—*Analysis of variance of the yield of rough rice in grams*

a. *Square*

SV	DF	SS	MS	COMP. F	PROB.
Strata	2	314160.54	175080.27	12.98	<.01
Farms within strata	9	108870.65	12096.73	5.67	<.01
Paddies within farms	12	35573.10	2131.09	0.29	>.05
Plots within paddies	24	176054.26	7335.59		
Total	47	634658.55			

S.M.D. (Strata):
At 5% = 87.87
At 1% = 126.26

S.M.D. (Farms within strata):
At 5% = 71.07
At 1% = 99.65

b. *Triangle*

SV	DF	SS	MS	COMP. F	PROB.
Strata	2	161035.39	80715.69	3.29	>.05
Farms within strata	9	220187.18	24465.25	5.79	<.01
Paddies within farms	12	50656.42	4221.36	0.42	>.05
Plots within p addies	24	242784.89	9885.75		
Total	47	674663.88			

S.M.D. (Farm within strata):
At 5% = 100.03
At 1% = 140.25

c. *Rectangle*

SV	DF	SS	MS	COMP. F	PROB.
Strata	2	372731.37	186365.68	18.73	<.01
Farms within strata	9	89532.50	9948.05	0.95	>.05
Paddies within farms	12	124882.78	10406.89	1.51	>.05
Plots within paddies	24	165164.55	6881.85		
Total	47	752311.20			

S.M.D. (Strata):
At 5% = 79.69
At 1% = 114.49

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SOCIAL AND ECONOMIC CONDITIONS OF COCONUT FARMERS IN CALOLBON, CATANDUANES [1]

JULIAN V. SANTELICES

In 1954-55, the average area of a farm in Calolbon, Catanduanes, was seven hectares; the average investment, ₱6,628. Coconut, the principal crop, was the main source of income. The farm receipts averaged ₱1,420, and the average farm expenses amounted to ₱360. The labor income averaged ₱248; labor earnings, ₱498; family income, ₱924; and the amount available for the family, ₱1,462, or an average of ₱292 for each member.

The average number of members to a household was five. Most of the houses had nipa roofs, wooden walls, and wooden floor. The home facilities and conveniences were very few.

The average schooling of the farm operator was five years, and that of the children, six years. There were few reading materials in the homes and most of these were old issues of local publications.

The improvement of the economic and social conditions of farmers is at present a vital national concern. Several government agencies and private organizations have been mobilized for a national program of rural community development. The effective implementation of this program requires a better understanding of the farmers' problems and needs.

Although surveys of the economic and social conditions of farmers have been undertaken in some regions of the Philippines, very little emphasis has been given to coconut farmers; hence, this investigation was conducted to study (1) their economic conditions, such as their type of farming, size of farm, crops grown, livestock raised, and income; and (2) their social conditions, such as the nature of their dwelling, household conveniences, educational attainment, and recreational activities.

In one of the earliest studies of the conditions of coconut farm-

[1] Central Experiment Station Contribution No. 1990. Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, March, 1956. Prepared in the Department of Agricultural Education under the direction of Assistant Professor Gil F. Saguiguit.

ers, Sacay and Gaac [2] reported that in Despujols, Romblon, the average area per farm was 3.4 hectares. Of the total farm area, 96.9 per cent was devoted to crops. The average capital investment was ₱3,963, of which 72.2 per cent was invested in land; only a small amount went to livestock and tools. Farm receipts averaged ₱1,874; of this amount 87 per cent came from coconut, and 10 per cent came from fruits and vegetables. The average farm expenses amounted to ₱694; labor income, ₱931; and the labor earning, ₱1,389. Of the family income, 94 per cent was earned by the operator.

The residents made little attempts to beautify their homes, and facilities and conveniences were very few. Most of the operators' children had an average schooling of six years.

In a similar survey in Sipocot, Camarines Sur, where coconut was the principal source of income, Serrano (1955)[3] reported that the average size of a farm was 12.3 hectares. The average capital investment was ₱5,456, of which 85 per cent was invested in land and the rest to livestock, tools, and supplies. Farm receipts averaged ₱3,008; farm expenses, ₱1,120; and labor income, ₱1,561. Very little attention was given to homeground improvement, and home facilities and conveniences were meager.

The present study included 100 farmers who were selected systematically from the barrios of Manambrag, Maygnaway, Codon, Cabcab, Lictin, Palawig, and the poblacion of Calolbon. The data of crop year 1954-1955 were secured through personal interviews with the farmers, their wives, and elder children, and were recorded in schedules prepared in the Department of Agricultural Education.

ECONOMIC CONDITIONS

Age, birthplace, and farming experience of operators. The farm operators ranged from 20 to 65 years old, or an average of 47 years. About 85 per cent were 35 years or older.

Forty-three of the 100 farm operators were born in the poblacion of Calolbon; about as many were born in the barrios of the municipality. A few were born in other towns and provinces.

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[2] F. M. Sacay and B. A. Gaac, *Philippine Agriculturist*, **36**, 225-229 (1949).

[3] Jose Serrano, "The Economic and Social Conditions of Coconut Farmers in Libmanan, Camarines Sur." (Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, October, 1955. Unpublished.)

The operators had resided in the barrios where they were farming for an average period of 23 years. Almost two-thirds of them had been residing in the barrios where they were farming for more than 20 years.

Farming experience. The farm operators had been farming for four to 59 years, or an average of 21 years, and five had been engaged in farming for more than 50 years.

Size of farms. The farms ranged from one to 15 hectares, or an average of seven hectares (table 1). This average area is five hectares less than that in Sipocot, Camarines Sur, as reported by Serrano (1955).[4]

TABLE 1.—*Size of farms*

AREA IN HECTARES	NUMBER
Below 1	0
1– 1.9	1
2– 2.9	11
3– 3.9	11
4– 4.9	10
5– 5.9	11
6– 6.9	17
7– 7.9	13
8– 8.9	7
9– 9.9	3
10–10.9	3
11–11.9	1
12–12.9	0
13–13.9	0
14–14.9	1
15 and above	11
Total	100
Average	7

Utilization of farm area and crops grown. About 99 per cent of the total farm area was planted to crops, and less than one per cent was utilized for farmsteads, gardens, and orchards. Coconut was the principal crop. Rice, corn, and sweet potato were the important secondary crops. Gabi, mungo, peanut, cassava, fruit trees, and vegetables were planted in very limited quantities (table 2). Some areas between coconut rows served as pastures.

[4] *Ibid.*

TABLE 2.—*Utilization of farm area and crops grown*

CROP	NUMBER OF FARMS	AREA (HA.)	PROPORTION	AREA OF EACH FARM RAISING (HA.)	AVERAGE FOR ALL FARMS (HA.)
Farm crops:					
Coconut	100	407	55	4.1	4.1
Abacá	58	82	11	1.4	0.8
Rice	67	134	18	2.0	1.3
Corn	45	65	10	1.4	0.7
Sweet potato	59	42	6	0.7	[c]
Fruits and vegetables [a]	—	—	—	—	—
Farmsteads and gardens	—	2	[b]	[c]	[c]

[a] Fruit trees and vegetables were planted in insignificant areas.
[b] Less than one per cent.
[c] Less than half a hectare.

Capital investment. The average capital investment per farm was ₱6,628. Eighty-four per cent of this amount was invested in land and about 11 per cent in buildings. Since these were "going" farms, very little amount was spent after the first year of operation for tools and supplies (table 3).

TABLE 3.—*Capital investment*

FORM OF CAPITAL	TOTAL	AVERAGE	PER CENT
Land	₱556,093	₱5,561	84
Buildings	75,225	752	11
Tools and equipment	731	7	[a]
Work animals	18,049	180	3
Other livestock	12,426	124	2
Supplies	365	4	[a]

[a] Less than one per cent.

Livestock raised. Carabao, the major work animal, was found in 87 farms. There were three carabaos to a farm. Other livestock, such as goats and horses, and poultry were also raised. Thirteen farms did not report any work animal (table 4). The operators of these farms claimed that there was no need raising work animals since they could easily borrow from their neighbors whenever they needed animal power.

TABLE 4.—*Livestock raised*

LIVESTOCK RAISED	NUMBER OF FARMS	NUMBER OF ANIMALS	AVERAGE PER FARM
Work animal:			
Carabao	87	255	3
Other livestock			
Horses	8	10	1
Goats	89	316	4
Poultry:			
Chicken	88	646	7
Ducks	13	79	6

Receipts from crops. Coconut, which contributed 74 per cent of the total receipts from crops, was the main source of income. Abacá accounted for nine per cent; sweet potato and fruits and vegetables, 12 per cent; and rice and corn, only five per cent. Receipts from crops averaged ₱840.

Farm receipts. Table 5 shows that of the average total farm receipts of ₱1,420, farm crops and fruits and vegetables contributed 60 per cent; increase of capital, 13 per cent; and off-farm income, 19 per cent. Although not actually a part of farm receipts, off-farm income was included because off-farm occupations represented the use of the farmers' time and brought income for the support of his family. The inclusion makes it possible to compare farms with the farmer spending most of his time on the farm with those where part is spent in outside endeavors.

TABLE 5.—*Farm receipts* [a]

SOURCE	AMOUNT	PER CENT
Farm crops	₱ 789	56
Fruits and vegetables	51	4
Livestock and livestock products	115	8
Increase of capital	191	13
Off-farm income	274	19
Total	₱1,420	100

[a] Excluding the value of products used at home.

Farm expenses. The farm expenses averaged ₱360, the most important item of which was the harvesters' share, amounting to 47 per cent. Cash expenses amounted to 36 per cent (table 6).

TABLE 6.—*Farm expenses*

KIND OF EXPENSES	AMOUNT	PER CENT
Cash expenses	₱128	36
Unpaid family labor	63	17
Harvesters' share	169	47
Total	₱360	100

Farm privileges. Farm privileges averaged ₱250. Farm crops, including fruits and vegetables that were consumed at home, contributed 67 per cent; livestock and livestock products, 20 per cent; and the use of dwelling, 13 per cent.

Labor income. The labor income of a farmer averaged ₱248 (table 7). This amount represented a daily wage of less than a peso, assuming that a farmer worked every day of the year.

TABLE 7.—*Labor income*

ITEM	AMOUNT
Farm receipts	₱1,420
Farm expenses	360
Net farm income	1,060
Interest at 12% on average inventory	812
Labor income	₱ 248

Labor earning and family income. An operator had an average labor earning of ₱498 (table 8).

TABLE 8.—*Operator's labor earnings*

ITEM	AMOUNT
Labor income	₱248
Farm privileges	250
Total	₱498

The average total family income was ₱650. This included the operator's labor earnings and the income of the other members of the family in the amount of ₱152 (table 9).

TABLE 9.—*Family income*

ITEM	AMOUNT	PER CENT
Operator's income:		
From farm	₱224	
From off-farm job	274	
Total operator's income	498	77
Income of other members of the family:		
Unpaid family labor	63	
From off-farm job	89	
Total income of other members of the family	152	23
Total	₱650	100

Amount available for family living. The amount available for family living and saving was ₱1,462 or ₱292 for each member of a family with an average membership of five (table 10).

TABLE 10.—*Amount available for family living*

ITEM	AMOUNT
Net farm income	₱1,060
Farm privileges	250
Unpaid family labor	63
Family income from off-farm job	89
Amount available for family living	₱1,462

SOCIAL CONDITIONS

Types and size of household. The most common family composition was husband and wife and two or three children. This constituted 22 per cent. Seventy per cent of the families had two to five children.

There was an average of five members in each household. Thirty-nine per cent had six to 10 members. Most of the families had four to seven members.

Classification of household members. The total number of household members was 549. Thirty-six per cent were parents, 63 per cent were children, and one per cent were relatives. There were no laborers and other persons.

Classification of dwellings according to materials used. Ninety-four per cent of the houses had nipa roofings, and only six houses had G.I. roofings. No other roofing materials were used. Sixty houses had wooden walls and floor.

Size of dwelling and number of rooms. The floor area of a dwelling averaged 51 square meters, or eight to nine square meters to a person. The average number of rooms to a dwelling was three.

Value of dwellings. The average value of a dwelling was ₱752. About 14 per cent of the dwellings had values ranging from ₱501 to ₱600.

Home facilities and conveniences. Wooden benches, wooden chairs, beds, and a dining table were the most common conveniences. Other home facilities were ground wells, sewing machines, bicycles, and some iron chairs and beds.

Home beautification. The residents did not pay much attention to the beautification of their homes. About 67 per cent had potted plants in the house, 20 per cent had potted plants in the yard, and only nine per cent had climbing plants around the house.

Educational attainment of farm operators and their children. The farm operators had an average schooling of five years. About 18 per cent completed the primary grades; 14 per cent, the elementary grades; and four per cent, high school. Only two per cent finished a two-year college course. The operators' children had an average schooling of six years. Twelve per cent finished high school, and only about 10 per cent completed a four-year college course. Eight per cent had no schooling.

Reading matter. A majority of the residents had no reading matter. *Liwayway,* a Tagalog monthly, was found in 12 per cent of the homes, and old issues of local newspapers like *The Manila Times* and *The Manila Chronicle* were found in 15 houses.

Common recreational activities. Cockfighting, drinking tuba, and fishing were the most common recreational activities of the farmers. Among the wives, dancing, playing cards, and chatting with neighbors were common. The children's pastime included ball games, hunting, dancing, and singing.

Membership in organizations. Forty-nine fathers and 16 mothers were members of the parent-teacher association. Five fathers

and two mothers belonged to a religious organization. Nine sons and ten daughters participated in the 4-H club, and 16 children were members of the youth organization for community improvement. Only 11 were members of the Boy Scouts of the Philippines.

* * *

"A scientist who has received an average training is ignorant of all that does not enter into his specialties and 'knows.' We shall have to say that he is a *learned ignoramus,* which is a very serious matter as it implies that he is a person that is ignorant, not in the fashion of the ignorant man, but with all the petulance of one who is learned."

—*Ortega y Gasset*

* * *

"The spirit of generalization should dominate a university. The lectures should be addressed to those to whom details and procedure are familiar. . . . The function of the university is to enable you to shed details in favor of principles."

—*A. N. Whitehead*

GENERAL AND SPECIFIC COMBINING ABILITY OF S_2 COLLEGE WHITE FLINT AND S_3 BICOL WHITE FLINT INBRED LINES [1]

ONOFRE Q. BALLESTEROS [2]

Twenty-three inbred lines yielded significantly higher than the tester parent (Davao White Flint) for two seasons and in three locations in the tests for general combining ability. There was no significant interaction between topcrosses and locations and among topcrosses, locations and seasons. This indicates that a performance test to determine general combining ability, conducted at one location would suffice as a basis for either eliminating or including an inbred line in the subsequent specific combining ability tests.

In the test for specific combining ability, however, a highly significant interaction between locations and hybrids was obtained, which shows that performance tests must be conducted at more locations and seasons to obtain sufficient information on the yielding potentiality of the specific crosses.

Corn is one of the major crops of the Philippines. It ranks second to rice in area planted which is about 1,393,700 hectares or one-third of the total cultivated area. About six million people or 27.3 per cent of the total population eat corn.

Extensive research for the improvement of corn was started in 1949 by the College through D. L. Umali.[3] This systematic and well-planned program of corn breeding later on become the core of the Corn Improvement Program in the Philippines.

Although it is now possible to evaluate the general and specific combining ability of inbred lines early in the inbreeding generation, several research workers still consider the evaluation phase as the bottleneck in corn improvement.

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[2] Grateful acknowledgment is due Dr. D. L. Umali, thesis adviser; Drs. H. L. Everett and J. D. Soriano for invaluable suggestions in the preparation of the manuscript; and Don Andres Soriano for the Don Andres Soriano Research Fellowship which enabled the writer to finish all the requirements for the M.Sc. degree.

[3] Research Professor of the U.P. College of Agriculture and concurrently Director of the Rice and Corn Program.

General combining ability refers to the average performance of an inbred line in hybrid combination while specific combining ability refers to the inherent capacity of two inbred lines to combine.

This work aimed to (1) study the general and specific combining ability of S_2 College White Flint and S_3 Bicol White Flint inbred lines; (2) determine the desirable inbred lines adapted to College, Laguna, for Luzon; La Granja, Negros Occidental, for the Visayas; and Aroman, Cotabato, for Mindanao; and (3) obtain information on the adaptability to seasons and regions of corn hybrids developed from these inbred lines. The investigations were conducted from June, 1954, to February, 1958.

REVIEW OF LITERATURE

Inbred-variety Tests and the Selection of Testers

The laborious procedure of evaluating inbred lines by making all the possible combinations was revolutionized when Davis (1927) suggested the use of line-variety crosses or topcrosses. The general acceptance and use of the method, however, should be credited to the work of Jenkins and Brunson (1932). Jenkins (1929) concluded that the most productive crosses come from the most productive inbred parents and this conclusion was confirmed by the findings of Hayes and Johnson (1939).

The choice of a suitable tester undoubtedly poses an important problem in corn breeding. Studies which have direct bearing on the problem were those reported by Federer and Sprague (1947), Green (1948a), Keller (1949) and Matzinger (1953).

Beard (1940) suggested the use of a highly heterozygous single cross because it contains factors with strong dominance and epistatic effects although such a cross would undoubtedly contain factors affecting general combining ability. The use of related and unrelated single cross tester parents in evaluating new inbred lines was investigated by Keller (1949). In general, the data obtained indicated that a related and an unrelated single cross tester parent are about equal in efficiency when used in measuring combining ability. However, Grogan and Zuber (1957) obtained a lower mean square for the comparison of related single-cross tester, which suggests that one should not use a tester closely related to the lines being tested when information on general combining ability is desired.

Genetic Diversity and Inheritance of Combining Ability

The usefulness of an inbred line can be determined when harnessed with another inbred line of a different parentage.

Wu (1939) presented experimental results showing the relationship between hybrid vigor in crosses and the origin of corn inbred lines and concluded that crosses among inbred lines with no parent in common yielded much higher than crosses among inbred lines with one parent in common. Similarly, Hayes and Johnson (1939) obtained results showing a direct relationship between the origin of the inbred lines and the combining ability in single crosses.

Ballesteros (1955) studied the relationship between the yielding ability of single crosses and the degree of genetic diversity of the inbred lines and concluded that, in general, single crosses between inbred lines of considerable genetic diversity gave significantly higher yield than single crosses of closely related inbred lines.

Studies on the inheritance of combining ability have been reported by Johnson and Hayes (1939), Cowan (1943), and Green (1948b).

Prediction of Double Cross Yields

Four methods of predicting the performance of double crosses were reported by Jenkins (1934).

1. The average yield of the six possible single crosses from four inbred lines.

2. The average yield of the four single crosses not used as parental single crosses in making the double cross.

3. The average yield for each inbred line is obtained based on the yields of the single crosses of which it is a parent. The predicted yield is then the average of the four averages for the four inbred lines.

4. The predicted yield is the average of the yields of the inbred-variety crosses of the four inbred lines.

Correlation coefficients for yield of the different methods were calculated. The values obtained were 0.75, 0.76, 0.73, and 0.61 for the four methods, respectively. In discussing method 2, Jenkins stated that "in any double cross, the genes of each of the four parental lines are united only with the allelomorphs of the two lines which

entered the double cross from the opposite parent." Furthermore, Sprague (1955) indicated that method 2 permits the recognition of non-additive effects arising from dominance, epistasis, etc., while methods 1, 3 and 4 assume additive gene action, i.e., a gene contributed by a line will produce its characteristic regardless of the order of pairing.

MATERIALS AND METHODS

Sources of Inbred Lines

The two source varieties from which inbred lines were extracted are College White Flint and Bicol White Flint. These local varieties differ in many agronomic characters. College White, for example, is characterized by its narrow and erect leaves while Bicol White Flint has broad and drooping leaves. It was also observed that there was a wide variation in their reaction to insect pests and diseases.

Seventy-eight S_3 Bicol White Flint inbred lines and twenty-six S_2 College White Flint inbred lines developed by the pedigree method of breeding were used.

Test for General Combining Ability

Production of topcrosses. S_2 seeds of College White Flint inbred lines and S_3 seeds of Bicol White Flint inbred lines were planted on June 9, 1954, in an isolation plot for topcrossing. Each inbred line was planted in a row twenty hills long, spaced one-half meter between hills and one meter between rows with two replications. Four seeds were planted to a hill and thinned to two plants. Three plantings of the pollen parent were made to insure a continuous supply of pollen. The first planting was done five days before planting the seed parents, the second planting, concurrently with the seed parents, and the third planting, five days after the planting of the seed parents. To insure perfect seed setting the ratio used between the seed rows to pollen rows was 2:1.

The most ideal procedure should have been to topcross Bicol White Flint variety; however, available seed of these varieties was limited at the time of experimentation. It should be noted that the final double cross will not involve single crosses from Bicol White Flint and College White Flint because it was found that double crosses from these two varieties which are not genetically diverse in

origin gave lower yields than the double crosses from diverse inbred lines or single crosses.[4]

Performance tests of the topcrosses. During the dry season of 1954-55 and the wet season of 1955, performance yield tests of these topcrosses were conducted at the three experimental stations. The topcrosses with enough seed for three locations and two seasons were divided into four experimental subgroups of 16 entries. Each subgroup included the tester variety. In addition to the four subgroups, the College of Agriculture tested the remaining topcrosses which may be considered to consist another subgroup. This was done because of the limited seed produced from these topcrosses. Each experimental subgroup was a randomized-complete-block experiment. This design was used because of its simplicity and ease with which the experimental error is computed. Besides, the occurrence of missing plots does not present as much of a problem as when complicated designs are used; entries with missing plots can be omitted in the analysis of variance without serious harm (Hayes and Immer, 1942). Three replications were used.

Each plot consisted of two rows, 10 hills long. Rows were one meter apart; hills in rows were one meter apart. This made possible criss-cross cultivation which allows better weed control. Five seeds were planted to a hill and later thinned to three plants. Ammonium phosphate fertilizer (16-12-0) was applied at the rate of 250 kilograms per hectare two weeks after planting. Calibrated containers were used to insure a uniform rate of fertilizer application per hill.

The weight of the corn in cob from each plot was obtained before shelling and that of the shelled grain immediately after shelling. The moisture percentage of the shelled grain from each plot was determined with the use of the Universal Electronic Moisture Tester. Plot yields at the determined moisture content were converted to cavans per hectare at 15 per cent moisture by the use of the following formula:

$$Y = y \times \frac{10{,}000}{20} \times \frac{1}{54.06 \times 2.2} \times \frac{(100 - m)}{85} \times M$$

where Y = yield in cavans of shelled corn per hectare at 15 per cent moisture, y = weight of shelled corn for the plot in pounds, 10,000

[4] Unpublished data from corn yield tests conducted by the Division of Plant Breeding, Department of Agronomy, U.P. College of Agriculture.

= number of square meters per hectare, 20 = number of square meters occupied by a plot, 54.06 = number of kilograms of shelled corn per cavan, 2.2 = number of pounds per kilogram, m = moisture content of the shelled corn in per cent, and M = factor for missing hill.

The factor for missing hills was obtained by using this formula:

$$M = y \times \frac{\text{(No. of hills/plot)} - (0.3 \times \text{No. of missing hills/plot})}{\text{(No. of hills/plot)} - \text{(No. of missing hills/plot)}}$$

According to Jugenheimer, Bauman and Alexander (1954) this adjustment adds 0.7 of the average hill yield for each missing hill and assumes that 0.3 is made up by the increased yield of the surrounding hills.

The hectare yield of each topcross in three replications was further converted into percentage yield using as 100 per cent the yield of the tester parent in the experimental subgroup to which it belonged. This was done to make comparisons between entries from the different subgroups possible.

Specific Combining Ability Test of Inbred Lines

Production of three-way crosses. One of the recommended procedures in determining specific combining ability is to cross an inbred with a single cross of known performance. This is highly recommended especially when several inbred lines are to be tested. When only a few inbred lines are to be tested, however, it is suggested that all possible combinations be made.

The choice of a suitable tester depends upon the plan for which the selected high combining inbred line will be utilized. L314 × L315 was used as the tester because it is involved in the tentatively Seed-Board-approved white flint hybrid.

The different inbred lines were planted on November 8, 1956, in an isolation plot. L314 × L315, the pollen parent, was planted on November 2, 1956. This was done to synchronize the shedding of pollen with the emergence of the silks.

The 23 inbred lines were planted in rows twenty hills long, spaced one-half meter between hills and one meter between rows. Three seeds were planted to a hill and later thinned to two plants. Three rows of parents to one row of pollen parent was followed and

the seed rows were detasseled before pollen shedding. The crop was harvested in the second week of March, 1957.

Performance tests of the three-way crosses. Due to delayed harvest of the crop, only College and La Granja stations conducted yield tests in the 1957 wet season.

The three-way crosses were planted in a simple randomized complete block design with four replications. Included were Bicol White Flint, College White Flint and the Seed-Board-approved Philippine Hybrid No. 2, (L314 × L315) (A200 × A204).

Each plot consisted of two rows, 10 hills long. Rows were one meter apart. Five seeds were planted to a hill and later thinned to three plants. The stand of the crop was excellent. Ammonium sulfate fertilizer (20.5-0-0) was applied at the rate of 250 kg. per hectare when the plants were about knee-high. When the plants were fully eared, a typhoon damaged the plants heavily. Most of the plants root- and stalk-lodged. The number of missing hills in each plot was taken.

RESULTS AND DISCUSSION

Topcross performance of S_3 Bicol White Flint. The calculated average hectare yield in per cent of the tester parent (Davao White Flint) of the different topcrosses tested at three locations in the 1954-55 dry season and in the 1955 wet season is presented in a frequency distribution (table 1).

Since the entries were found under different experimental subgroups and since the first, second or third replication may not be the same in all subgroups, the effect due to replication was excluded; hence, the data were analyzed as if there were no replications.

The computed F-value of the 1954-55 dry season test at College, Laguna, was significant at 5 per cent level in spite of the exceedingly high coefficient of variation (23.9 per cent). The wet season test showed no significance although the coefficient of variation was very much lower. Insignificant results were obtained from the 1954-55 dry season and 1955 wet season tests at La Granja Experiment Station, Negros Occidental. The coefficient of variability was 36.7 per cent for the dry season and 13.8 per cent for the wet season. It is significant to note that where the yield levels were low, the relative

TABLE 1.—*Frequency distribution of the mean hectare yields in per cent of the yield of the tester parent of the S_3 Bicol White Flint inbred lines tested for two seasons at three locations*

YIELD RANGE IN PER CENT	LOCATION					
	College		La Granja		Aroman	
	1954-55	1955	1954-55	1955	1954-55	1955
70.0–79.9	3	1	—	—	—	4
80.0–89.9	6	4	1	—	1	8
90.0–99.9	8	17	—	—	5	4
100.0–109.9	15	31	1	6	6	5
110.0–119.9	20	19	1	16	3	3
120.0–129.9	10	6	5	8	6	4
130.0–139.9	7	—	3	1	2	1
140.0–149.9	6	—	4	1	3	1
150.0–159.9	2	—	4	—	3	1
160.0–169.9	1	—	2	—	1	—
170.0–179.9	—	—	—	—	1	—
180.0–189.9	—	—	2	—	1	—
190.0–Above	—	—	1	—	—	—
Total	78	78	24	32	32	31

yields were high and vice versa. This was due to the extremely low yield of the tester parent (Davao White Flint) during an abnormal condition, indicating the superiority of the hybrids in an adverse condition.

The 1954-55 dry season at Aroman, Cotabato, was highly significant but no statistical significance was noted in the 1955 wet season test. The lack of significance is due probably to the exceedingly high coefficient of variability (43.8 per cent). The high coefficient of variability was attributed to rat and wild hog damage and to soil differences. Salmon (1956) mentioned variation in soil, rainfall, temperature, diseases, and insect pests as possible causes of high coefficient of variation.

The mean for three replications for the actual and relative yields per hectare at 15 per cent moisture of the S_3 Bicol White Flint topcrosses grown in the 1955 wet season at College, Laguna, ranged from 56.7 cavans or 78.8 per cent (32-B-239-3-1 × DWF) of the tester parent. The computed F-value did not reach the 5 per cent level of significance which indicated that the yield performance of the different topcrosses was about the same although a difference of 26.7 cavans or 43.7 per cent was noted between the highest and the lowest yielding topcrosses.

It is interesting to note that the 1955 wet season yield test was very much better and more reliable than the 1954-55 dry season yield test as indicated by the lower coefficient of variations of the different experimental subgroups. Furthermore, higher yields were obtained due to the very favorable growing conditions.

Performance of S_2 College White Flint Topcrosses

The actual and relative mean hectare yields at 15 per cent moisture of the different S_2 College White Flint topcrosses grown in the 1954-55 dry season and in the 1955 wet season at the College of Agriculture, College, Laguna, are presented in table 2.

TABLE 2.—*Mean hectare yield in cavans (actual and relative) at 15 per cent moisture content of S_2 College White Flint Topcrosses tested at College, Laguna*

ENTRY	MEAN HECTARE YIELD			
	1954-55		1955	
	Actual	Relative	Actual	Relative
32-CW-6-1 × DWF	24.6	97.0	68.0	04.2
-19-1 × DWF	30.8	127.8	71.3	99.4
-26-1 × DWF	22.5	90.2	72.9	101.4
-55-1 × DWF	20.2	83.3	76.1	105.9
-56-2 × DWF	26.2	106.8	67.5	94.1
-59-1 × DWF	25.6	107.6	70.6	98.4
-78-1 × DWF	28.8	119.5	69.1	96.0
-98-1 × DWF	18.9	80.2	71.3	98.3
-101-1 × DWF	24.5	100.4	66.2	91.9
-104-1 × DWF	24.5	99.1	72.3	100.2
-6-2 × DWF	27.2	109.2	67.6	93.9
-14-1 × DWF	37.6	151.7	69.2	96.2
-16-1 × DWF	34.6	139.6	81.6	113.7
-16-2 × DWF	30.9	140.5	69.8	102.3
-19-2 × DWF	26.5	118.9	63.7	93.2
-22-1 × DWF	31.9	143.7	66.8	97.9
-22-2 × DWF	27.6	124.5	67.2	98.7
32-CW-23-1 × DWF	33.6	151.7	69.5	102.0
-23-2 × DWF	33.3	151.5	69.1	101.4
-34-1 × DWF	26.6	120.3	65.8	96.2
-35-1 × DWF	29.1	131.6	59.6	87.1
-38-1 × DWF	32.0	146.3	62.4	91.0
-52-1 × DWF	28.9	130.7	69.5	101.6
-56-3 × DWF	20.5	94.1	67.2	98.5
-75-1 × DWF	20.4	91.3	66.4	97.4
-104-2 × DWF	34.0	153.9	75.2	110.3

Analysis of variance (relative yield)

SOURCE OF VARIATION	DF	1954-55		1955	
		MS	CF	MS	CF
Between topcrosses	25	1,636.49 [a]	2.23	98.32 [b]	0.93
Within topcrosses	52	735.26		105.95	

[a] Significant at one per cent level.
[b] Not significant.

The relative mean yield was calculated based on the hectare yield of the tester parent for every replication (table 2). The environmental effects were eliminated because the replications in one experimental subgroup were not similar to the replications in another subgroup.

Five topcrosses yielded significantly higher than the tester parent in the 1954-55 dry season. A high coefficient of variation (22.7 per cent) was obtained.

When the actual hectare yields were statistically analyzed separately, these topcrosses significantly outyielded the tester parent at one per cent level and an additional seven at five per cent level. More topcrosses showed significantly better yields than the tester parent when analyzed separately owing probably to the pooling effect of the topcrosses, thus resulting in a high experimental error which may be ascribed to experimental subgroup difefrences.

Although the coefficient of variability was lower (10.4 per cent) in the 1955 wet season than in the 1954-55 dry season test, the topcrosses did not vary significantly, which indicates that the tester parent was inefficient in differentiating the yield components of the different inbred lines under favorable growing conditions.

Due to several missing plots in the 1954-55 performance test conducted at the La Granja Sugarcane Experiment Station, La Granja, Negros Occidental, the reasons for which were not reported, the two experimental subgroups of S_2 College White Flint topcrosses were discarded. However, the 1955 wet season performance test was satisfactory; hence the results were tabulated in table 3.

There was no significant difference in the grain yields of the twenty-six S_2 College White Flint topcrosses. There is an indication, however, that some inbred lines combined well with the tester parent. Although there was lack of statistical significance, the test was con-

TABLE 3.—*Mean actual and relative hectare yields at 15 per cent moisture*

ENTRY	ACTUAL	RELATIVE
32–CW–6–1 × DWF	76.6	128.1
–19–1 × DWF	66.4	110.9
–26–1 × DWF	62.1	103.6
–55–1 × DWF	66.3	110.5
–56–2 × DWF	62.6	104.0
–59–1 × DWF	62.6	104.2
–78–1 × DWF	56.1	93.1
–98–1 × DWF	65.8	109.0
–101–1 × DWF	59.3	98.6
–104–1 × DWF	70.4	117.1
–6–2 × DWF	57.0	95.2
–14–1 × DWF	63.1	105.2
–16–1 × DWF	71.9	120.5
–16–2 × DWF	72.8	119.8
–19–2 × DWF	61.9	102.3
–22–1 × DWF	63.6	105.3
–22–2 × DWF	66.0	108.9
–23–1 × DWF	68.6	113.9
–23–2 × DWF	66.5	109.8
–34–1 × DWF	66.3	109.7
–35–1 × DWF	66.8	110.4
–38–1 × DWF	65.3	107.8
–52–1 × DWF	60.7	100.1
–56–3 × DWF	63.8	105.5
–75–1 × DWF	62.0	102.4
–104–2 × DWF	65.9	108.8

sidered valid considering its low coefficient of variability (10.3 per cent).

The 1954-55 dry and 1955 wet season results of the performance test at the Mindanao Central Experiment Station, Aroman, Cotabato, are given in table 4. The analysis of variance for both seasons of tests show that the topcrosses were not significantly different.

Topcrosses-Location-Season Interaction

The yielding potentiality of crop plants is the result of the interaction of genes and environment; hence, whether or not a corn hybrid will be recommended depends on its performance as influenced by season and location. If the performance of hybrids were only

TABLE 4.—*Mean hectare yields at 15 per cent moisture*

ENTRY	CAVANS PER HECTARE	
	1954-55	1955
	dry season	*wet season*
32-CW-6-1 × DWF	30.9	36.4
-19-1 × DWF	36.3	33.1
-26-1 × DWF	35.9	26.6
-55-1 × DWF	34.8	29.9
-56-2 × DWF	34.8	29.6
-59-1 × DWF	33.0	26.7
-78-1 × DWF	29.4	26.7
-98-1 × DWF	30.9	17.6
-101-1 × DWF	27.5	25.0
-104-1 × DWF	36.6	26.0
Davao White Flint	24.3	26.0

Analysis of variance

SOURCE OF VARIATION	DF	1954-55		1955	
		MS	CF	MS	CF
Varieties (V)	10	47.89 [a]	1.74	69.51 [a]	1.12
Replication (R)	2	19.60		116.86	
V × R	20	27.49		61.94	

[a] Not significant.

meagerly influenced by environment, then tests conducted at a single location for a single year would suffice in providing adequate information for elimination or recommendation. However, this ideal situation does not usually occur, thereby necessitating the repetition of experiments over a number of years and locations. Results derived from any single experiment or trial were valid only for a particular season and soil in which the experiment was conducted.

With the use of Bartletts Chi-square test ($P > 99$) the error variances of the three locations and two seasons were found homogeneous. Thus, the data obtained could be appropriately pooled.

The pooled analysis of variance for the S_3 Bicol White Flint topcrosses, fourteen experimental subgroup I and twelve topcrosses for experimental subgroup II, together with the tester parent, shows an insignificant interaction between topcrosses and location and among topcrosses, locations and seasons (table 5).

This indicates that topcrosses performing markedly well in one location perform likewise in another location. This further indicates the possibility of a corn hybrid that could be grown throughout the islands although performance tests were limited to few locations.

TABLE 5.—*Interaction analysis of variance*

SOURCE OF VARIANCE	GROUP I		GROUP II	
	DF	MS	DF	MS
Location (L)	2	5,923.88	2	6,395.31
Season (S)	1	37,886.84	1	34,141.13
Reps. within season and location (R)	12	170.73	12	56.06
Variety (V)	13	173.52	11	83.83
L × V	26	51.50 [a]	22	59.38 [a]
V × S	2	17,938.96 [b]	2	15,748.65 [c]
L × V × S	26	35.58 [a]	22	55.32 [a]
Pooled error	156	35.48	122	36.01

[a] Not significant.
[b] Significant at five per cent level.
[c] Significant at one per cent level.

Specific Combining Ability Test

Grain yield. The mean hectare yields at 15 per cent moisture of the twenty 3-way crosses, the Seed-Board-approved White Flint hybrid, Bicol White Flint variety and College White Flint variety were arranged in descending order for College, Laguna, but not so for La Granja, Negros Occidental (table 6).

The analysis of variance for each location shows a highly significant difference between varieties. The yield levels at College ranged from 27.0 cavans to 55.1 cavans while the yield levels at La Granja ranged from 15.5 cavans to 30.7 cavans.

When the three-way crosses were compared to the Seed-Board-approved White Flint hybrid, Philippine Hybrid No. 2, the results showed that seven entries were highly significant and three additional entries were significant only at five per cent level; but when the three-way crosses were compared to Bicol White Flint variety, four entries became significant at five per cent level. The significant mean differences at .05 and .01 levels were 5.3 and 7.0 cavans, respectively, with an extremely low coefficient of variability (8.4 per cent) in spite of the serious damage due to typhoons. Two 3-way crosses gave lower mean yields than Philippine Hybrid No. 2

TABLE 6.—*Mean hectare grain yields (in cavans) at 15 per cent moisture of three-way crosses tested in the 1957 wet season*

ENTRY	COLLEGE	LA GRANJA
Ph 10 × (L314 × L315)	55.1	22.3
Ph 4b × "	53.7	25.8
Ph 22a × "	52.4	25.8
Ph 4a × "	51.3	30.7
Ph 13b × "	51.1	22.3
Ph 26a × "	48.4	17.1
Ph 28a × "	47.6	24.7
Ph 28b × "	47.5	21.5
Ph 8a × "	47.4	22.0
Ph 6 × "	46.4	22.8
Ph 28c × "	45.1	30.0
Ph 16a × "	42.7	16.1
Ph 22b × "	42.4	21.6
Ph 30 × "	41.6	24.5
Ph 26b × "	41.4	22.5
Ph 16b × "	41.3	19.2
Ph 12 × "	41.2	19.0
Ph 18a × "	41.2	—
(L314 × L315) (A200 × A204)	40.6	21.3
Bicol White Flint variety	38.4	22.9
Ph 24b × (L314 × L315)	37.9	15.5
Ph 24a × "	35.8	20.4
College White Flint variety	27.0	16.6

Analysis of variance

SOURCE OF VARIATION	DF	COLLEGE			LA GRANJA		
		MS	S.M.D.		MS	S.M.D.	
			.05	.01		.05	.01
Variety (V)	21	175.25 [a]	5.3	7.0	63.53 [a]	6.7	8.9
Replication (R)	3	21.13			105.11		
V × R	63	13.79			22.62		

[a] Significant at one per cent level.

and Bicol White Flint variety. The difference in yield, however, was not significant.

Ph 4a × (L314 × L315) and Ph 28c × (L314 × L315) outyielded the white flint hybrid at one and five per cent levels, respectively, in the test conducted at La Granja, Negros Occidental; when these two 3-way crosses were compared to Bicol White Flint, both

reached only the five per cent level of significance. The significant mean differences were 6 .7 cavans at .05 and 8.9 cavans at .01 per cent.

Variety-location interaction. Table 7 shows the analysis of variance of the grain yields at 15 per cent moisture of the different 3-way crosses grown at College, Laguna, and La Granja, Negros Occidental, in the 1957 wet season.

TABLE 7.—*Pooled analysis of variance of the hectare grain yields at 15 per cent moisture of the three-way crosses test in the 1957 wet season at College and La Granja*

SOURCE OF VARIATION	DF	MS
Location (L)	1	21,972.28 [a]
Reps within location (R)	9	42.08
Entry (E)	21	175.18 [a]
L × E	21	63.59 [a]
Pooled error	123	18.65

[a] Significant at one per cent level.

The variances for locations, entries and location-entry were highly significant. It is interesting to note that the computed F-value of location-entry interaction exceeded the one per cent level indicating that the variance components of genotype-environment interactions was an important constituent of specific combining ability. Similar findings were reported by Rojas and Sprague (1952). This suggested further that where specific combining ability is the primary interest, tests must be conducted at more locations and seasons. This is not necessary, however, if general combining ability is the primary concern.

Prediction of double cross yields. The predicted yield of a double cross that may be developed from a three-way cross is obtained by averaging the mean yields of two 3-way crosses. Based on the performance of the different three-way crosses in one season at two locations, ten entries which significantly outyielded Philippine Hybrid No. 2 (L314 × L315) (A200 × A204) were selected. Thus, for 10 inbred lines, 45 different single crosses can be made, and 630 different double crosses are possible.

Since the experimental error in the test conducted at La Granja was rather high (21.6 per cent) the results obtained may not be

very reliable. Hence, in the prediction of double cross yields only the College data were used. The predicted yields of the double crosses ranged from 54.4 to 46.9 cavans (table 8). These predicted yields should not be considered too seriously because they are based on results of only one test in one season and in one location.

TABLE 8.—*Predicted hectare yields in cavans of double cross among 45 single crosses and L314 × L315*

INBRED LINE	Ph 10	Ph 4b	Ph 22a	Ph 4a	Ph 18b	Ph 26a	Ph 28a	Ph 28b	Ph 8	Ph 6
Ph 10	—									
Ph 4b	54.4	—								
Ph 22a	53.8	53.1	—							
Ph 4a	53.2	52.5	51.9	—						
Ph 18b	53.1	52.4	51.8	51.2	—					
Ph 26a	51.8	51.1	50.4	49.9	49.8	—				
Ph 28a	51.4	50.7	50.0	49.5	49.4	48.0	—			
Ph 28b	51.3	50.6	50.0	49.4	49.3	48.0	47.6	—		
Ph 8	51.3	50.6	49.9	49.4	49.3	47.9	47.5	47.5	—	
Ph 6	50.8	50.1	49.4	48.9	48.8	47.4	47.5	47.0	46.9	—

Table 9 summarizes the predicted high-yielding double crosses between single crosses of Bicol White and College White Flint inbreds and a single cross of Colombia variety inbreds (L314 × L315).

Due to the typhoon that occurred when the plants were already well-eared, the percentage of broken stalks was extremely high. This phenomenon, however, was advantageous from the standpoint of selection for it helped in eliminating lines with weak stalks. The percentages of broken stalks were transformed to angles corresponding to percentages as given by C. I. Bliss (Snedecor, 1946). The analysis of variance shows a significant difference between the different entries. Nine 3-way crosses had a significantly lower percentage of broken stalks than Bicol White Flint and eight 3-way crosses had a significantly lower percentage of broken stalks than (L314 × L315) (A200 × A204).

The different 3-way crosses silked in 56 to 61 days, Philippine Hybrid No. 2 silked in 60 days which did not differ significantly from the number of days to silking of the 3-way crosses. The Colombian single cross (L314 × L315) might be responsible for the late characteristic of the 3-way crosses.

TABLE 9.—*Predicted high yielding double crosses between Bicol White Flint and College White Flint single crosses and L314 × L315 single cross*

DOUBLE CROSS		YIELD (CAVANS)	STALK LODGING	DAYS TO SILKING
(Ph 10 × Ph 4b)	(L314 × L315)	54.4	47.3	59
(Ph 10 × Ph 22a)	"	53.8	32.8	59
(Ph 10 × Ph 4a)	"	53.2	56.4	58
(Ph 10 × Ph 18b)	"	53.1	38.2	59
(Ph 10 × Ph 26a)	"	51.8	44.1	59
(Ph 10 × Ph 28a)	"	51.4	34.6	59
(Ph 10 × Ph 28b)	"	51.3	33.9	59
(Ph 10 × Ph 8)	"	51.3	33.3	60
(Ph 10 × Ph 6)	"	50.8	39.4	59
(Ph 4b × Ph 22a)	"	53.1	34.8	58
(Ph 4b × Ph 4a)	"	52.5	58.4	58
(Ph 4b × Ph 18b)	"	52.4	40.2	59
(Ph 4b × Ph 26a)	"	51.1	46.1	59
(Ph 4b × Ph 28a)	"	50.7	36.6	58
(Ph 4b × Ph 28b)	"	50.6	35.9	59
(Ph 4b × Ph 8)	"	50.6	35.9	59
(Ph 4b × Ph 6)	"	50.1	41.4	59
(Ph 22a × Ph 4a)	"	51.9	43.9	58
(Ph 22a × Ph 18b)	"	51.8	25.7	59
(Ph 22a × Ph 26a)	"	50.4	31.6	59
(Ph 22a × Ph 28a)	"	50.0	22.1	58
(Ph 22a × Ph 28b)	"	50.0	21.4	59
(Ph 22a × Ph 8)	"	49.9	20.8	59
(Ph 22a × Ph 6)	"	49.4	26.9	59
(Ph 4a × Ph 18b)	"	51.2	49.3	58
(Ph 4a × Ph 26a)	"	49.9	55.2	58
(Ph 4a × Ph 28a)	"	49.5	45.7	58
(Ph 4b × Ph 28b)	"	49.4	45.0	58
(Ph 4a × Ph 8)	"	49.4	44.4	59
(Ph 4a × Ph 6)	"	48.9	50.5	58
(Ph 18b × Ph 26a)	"	49.8	36.9	59
(Ph 18b × Ph 28a)	"	49.4	27.4	59
(Ph 18b × Ph 28b)	"	49.3	26.8	59
(Ph 18b × Ph 8)	"	49.3	26.2	60
(Ph 18b × Ph 6)	"	48.8	32.3	59
(Ph 26a × Ph 28a)	"	48.0	33.3	59
(Ph 26a × Ph 28b)	"	48.0	32.7	59
(Ph 26a × Ph 8)	"	47.9	32.1	60
(Ph 26a × Ph 6)	"	47.4	38.2	59
(Ph 28a × Ph 28b)	"	47.6	23.2	59
(Ph 28a × Ph 8)	"	47.5	22.6	59
(Ph 28a × Ph 6)	"	47.5	28.7	59
(Ph 28b × Ph 8)	"	47.5	21.9	60
(Ph 28b × Ph 6)	"	47.0	28.0	59
(Ph 8 × Ph 6)	"	46.9	27.4	60

SUMMARY AND CONCLUSIONS

1. The pooled analysis of variance for the S_3 Bicol White Flint topcrosses with complete yield data for two seasons at three locations showed insignificant interaction between topcrosses and locations and among topcrosses, locations and seasons. This indicates that in the determination of general combining ability, a performance test conducted at one location would be sufficient as a basis for eliminating or including an inbred line in a specific combining ability test.

2. The twenty-three inbred lines with high general combining ability were further tested for their inherent ability to combine with each other in specific crosses using a single cross (L314 × L315) of known performance.

Since a highly significant interaction between location and 3-way crosses was obtained in the determination of specific combining ability, it is imperative that performance tests be conducted at more locations and seasons to obtain sufficient information on yielding potentiality of the specific crosses.

3. In general, the topcrosses silked later during a period of drought or in the 1954-55 dry season than when the growing conditions were ideal or in the 1955 wet season.

4. Ten high combining inbred lines were obtained and their predicted yields to a hectare ranged from 54.4 to 46.9 cavans. Crosses of these inbred lines significantly outyielded Philippine Hybrid No. 2 and Bicol White Flint variety.

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ANTHRACNOSE OF CORN [1]

FLORENDO C. QUEBRAL

WITH THREE TEXT FIGURES

Anthracnose of corn is common among cereals and grasses. The symptom of the disease consists of brown, irregular spots with indistinct reddish-brown borders. The disease is caused by *Colletotrichum graminicolum* (Ces.) G. W. Wils, which grows abundantly on agar media. The fungus produces conidia which remain viable for four months. It can be disseminated by wind, insects, and other agents, and lives over from season to season in the form of dormant mycelium within infected tissues.

The corn varieties P.I. Yellow Sweet, College Yellow Flint, Cuban Yellow, Catambay's Cuban, Bicol White, Nueva Ecija White, and I 20 Sib were found susceptible to the disease. Cross-inoculation experiment showed that a number of grasses can be infected by the fungus.

The disease may be controlled by crop rotation, sanitation, other cultural practices and spraying the plants with fungicides such as Bordeaux mixture, Orthocide 50, Yellow Cuprocide, and Manzate.

Anthracnose of corn, caused by *Colletotrichum graminicolum* (Ces.) G. W. Wils., is a disease common among cereals and grasses. It brings considerable damage to Sudan grass and corn by reducing vigor in the plants and causing premature ripening or dying. According to Dickson,[2] anthracnose is associated with conditions of low or unbalanced soil fertility, open coarse soil, and continuous grass-cereal culture.

Since very little is known of anthracnose and its harm on corn in the Philippines, a study of the disease and its control was conducted from December, 1953, to March, 1955, in the Department of Plant Pathology and in the Central Experiment Station and vicinity.

THE DISEASE

History and geographical distribution. Anthracnose is known in North America and in Europe but no report of its occurrence in the Orient has been published. During the previous corn-growing

[1] Central Experiment Station Contribution No. 1992. Thesis presented for graduation with the degree of Bachelor of Science in Agriculture from the College of Agriculture, March, 1955. Prepared in the Department of Plant Pathology under the direction of Research Assistant Professor Faustino T. Orillo.

[2] J. G. Dickson, "Diseases of Field Crops," New York, McGraw-Hill Book Company, Inc., 1947, 405 pp.

season it was observed on a number of corn varieties planted by the Plant Breeding Division, Department of Agronomy of this College. The disease was particularly severe on a number of lines introduced from Mexico.

Symptoms. The early symptom of the disease is the presence of small, round or irregularly shaped, water-soaked spots on the leaves. The lesions are semi-transparent and without distinct borders. They may originate on any part of the leaf blade. Under favorable conditions the spots enlarge in size, the majority attaining a diameter of 15 millimeters. They become brown at the center with indistinct reddish-brown borders (fig. 1).

Fig. 1.—Portions of corn leaves showing early (left) and advanced (center and right) symptoms of the disease (×⅔). (*Photograph taken by the Photographic Division*).

As the disease progresses, the spots coalesce, covering large areas of the leaf. Eventually the diseased leaf shrivels, dies, and falls off. After moist weather, numerous small black specks develop on the dead infected tissues.

CAUSAL ORGANISM

Sections of diseased corn leaves were planted on plates of potato-dextrose agar to isolate the fungus. After three days, bits of mycelium were transferred from the plates to agar plants. To insure the isolation of the right fungus the single-spore strain method of isolation was employed. Subcultures from these two transfers were used in inoculation experiments and in morphological and cultural studies.

MORPHOLOGY

Mycelium. The mycelium of the fungus grows abundantly in pure culture. The hyphae are septate, sparingly branched, hyaline, granular, and thin-walled when young. They produce white flocculent aerial growth on agar media. As the hyphae grow older, they become vacuolate and thicker walled (fig. 2A). Measurements of 100 hyphal cells taken from 15-day-old cultures on potato-dextrose agar show that they are from 18.3 to 76.5μ in length and 3.3 to 6.6μ in diameter. The average size is $44.1 \pm 1.62 \times 4.4 \pm 0.13$.

Acervuli. The acervuli are partly buried in the medium and in the host tissues. They are oval or round and vary in size. Sanford [3] observed the same characteristics of acervuli produced on *Avena*. Under moist conditions, the acervuli can be seen as small specks scattered all over the infected tissues. They are dark brown and thick and produce abundant short, hyaline, non-septate conidiophores. Long, sterile, thick-walled, brown septate setae are produced among the conidiophores (fig. 2B). The setae are from 36.6 to 166.5μ in length and 3.3 to 9.9μ in diameter. The average diameter is $95.5 \pm 3.67\mu$.

Conidiophores. The conidiophores produced in the acervuli are short, erect, hyaline, non-septate and unbranched. They are numerous and crowded within the acervulus (fig. 2B). A single conidium is borne at the tip of each conidiophore. The conidiophores

[3] G. B. Sanford, *Sci. of Agric.* **15**, 370 (1935).

are from 4.9 to 13.3 × 1.6 to 3.3μ in size. The average size is 9.3 ± 0.26 × 3.1 ± 0.05μ.

Conidia. The conidia are non-septate and cylindrical when young, becoming sickle-shaped with age (fig. 2C). They are granular, thin-walled, hyaline, borne singly at the tips of the conidiophores, and easily detached. At germination they appear empty because the contents travel to the germ tube and appresorium (fig. 2D). Measurements of 200 conidia from infected corn tissues show that the length ranges from 19.8 to 33.3μ, and the width, from 6.6 to 9.9μ. The average size is 27.3 ± 0.24 × 8.9 ± 0.02μ.

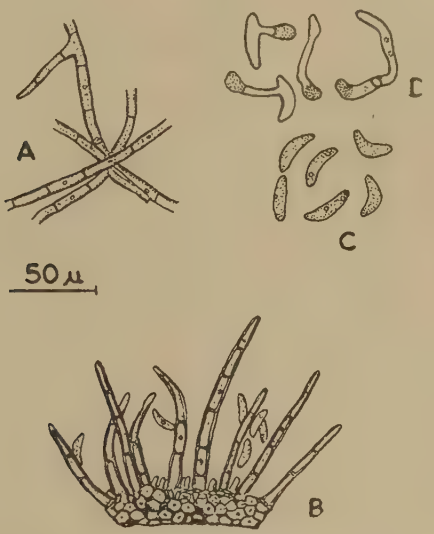

Fig. 2.—Camera lucida drawings: (A) mycelium of *Colletotrichum graminicolum* taken from a 15-day-old potato-dextrose agar culture, (B) acervulus showing the arrangement of conidiophores, conidia, and setae, (C) conidia, and (D) conidia germinating in distilled water.

PHYSIOLOGY

Production of ascigerous stage. Subjecting the fungal cultures to 10°C from one to four weeks did not effect the production

of asci. Boiling temperature (100°C) for a few seconds induced the production of small dark specks four weeks after treatment. Microscopic examination however revealed that they were not ascigerous. Likewise, desiccation, anaerobic condition and chloroform and formaldehyde vapors did not induce ascus formation.

Growth and conidium production of the fungus on various agar media and substrates. The growth characteristics and conidium production of the fungus were studied on culture media—potato-dextrose agar, onion agar, malt agar, rice decoction agar, water agar, Czapek's solution agar, dehydrated corn meal agar, nutrient gar, oatmeal agar, bean agar, coconut agar, and rice agar and on substrates—rice stem, corn stem, potato tubers, sugar cane stalk, Merker grass, Para grass, cornmeal, and Guinea grass.

In the first experiment triplicate cultures in slants planted to a bit of potato-dextrose agar containing hyphae of the fungus were made for each medium. The slants were incubated at room temperature and the sporulation of the fungus was observed daily for six days. In the second experiment triplicate cultures in Petri dishes were made for each medium. The plated media were planted at the center to a bit of mycelial fragment. The amount of inoculum transferred to each plate was made as uniform as possible. The planted plates were incubated at room temperature and the diameter of the colonies and sporulation of the fungus were observed daily for six days. The changes in color of the fungus were referred to Ridgeway's [4] color standards.

The growth characteristics and sporulation of the fungus on the different agar media are summarized in table 1.

The different substrates cut to a length of two to three inches were placed inside test tubes with wet cotton at the bottom. Triplicates of each substrate were autoclaved, inoculated with the causal organism, and incubated. Mycelial growth and production of spores were observed for two weeks.

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[4] Robert Ridgeway, "Color Standards and Color Nomenclature," Washington, D.C., Robert Ridgeway, 1912, 43 pp.

TABLE 1.—*Growth characteristics and conidium production of Colletotrichum graminicolum on various agar media*

MEDIUM	GROWTH CHARACTERISTICS	PRODUCTION OF CONIDIA	DIAMETER OF COLONY AFTER 6 DAYS [a]	AVERAGE DAILY GROWTH
			mm.	*mm.*
Potato-dextrose agar	Very abundant, white aerial mycelium produced within 24 to 48 hours; cultural medium changed from pale neutral gray to deep bluish gray green with light vinaceous lilac margin	abundant	51.1	8.56
Oatmeal agar	Fairly abundant loose, white aerial mycelium produced within 24 to 48 hours; medium changed from pale neutral-gray to deep blue gray	abundant	46.7	7.73
Onion agar	Fairly abundant loose, white mycelium produced within 24 to 48 hours; cultural medium changed from pale neutral gray to light grayish olive	fairly abundant	49.6	8.20
Malt agar	Abundant mycelial growth, white to dull white produced within 24 to 48 hours; cultural medium changed from neutral gray to light grayish olive	scarce	47.8	7.96
Corn meal agar	Fairly thin, white flocullent mycelium produced within 24 hours; cultural medium changed from dull white to pallid mouse gray	fairly abundant	38.5	6.46

TABLE 1 (Continued)

MEDIUM	GROWTH CHARACTERISTICS	PRODUCTION OF CONIDIA	DIAMETER OF COLONY AFTER 6 DAYS [a]	AVERAGE DAILY GROWTH
			mm.	*mm.*
Nutrient agar	Scarce, white to dull white mycelium produced within 2 to 3 days; cultural medium changed from pale neutral gray to deep blue gray	fairly abundant	34.2	5.74
Rice decoction agar	Thin, white loose mycelial growth produced within 2 to 3 days; cultural medium remain white to dull white	none	49.3	8.22
Bean agar	Scarce, white aerial mycelium produced within 24 hours; cultural medium changed from dull white to pale neutral gray	scarce	33.6	5.62
Rice agar	Abundant, white to dull white mycelial growth produced within 24 to 48 hours; cultural medium changed from neutral gray to deep olive gray with begonia rose margin	fairly abundant	50.5	8.43
Coconut agar	Fairly thin, white to milky white mycelium produced within 24 to 48 hours; cultural medium changed from pale neutral gray to deep olive gray	fairly abundant	44.2	6.10
Czapek's agar	Abundant, white to dull white aerial mycelial growth produced within 2 to 3 days; cultural medium changed from neutral gray to gray (dark gull gray)	scarce	32.2	5.33
Water agar	No growth produced	none		

[a] Average of three cultures.

The fungus showed comparatively good growth on all the substrates except on rice stems where mycelial growth was slight. Sporulation was abundant on sugar cane stalks, Merker grass, cornmeal, Guinea grass, and Para grass. Although growth of mycelium was good on potato tuber, very few spores were observed.

Effect of varying hydrogen-ion concentrations on growth and conidium production of the fungus. The fungus was grown on potato-dextrose agar with pH ranging from 1.4 to 10.4 (fig. 3). The agar medium was adjusted to the desired pH by the addition of either N/10 HCl or N/10 NaOH. The pH reading was determined with the aid of a La Motte colorimeter. Triplicate cultures were

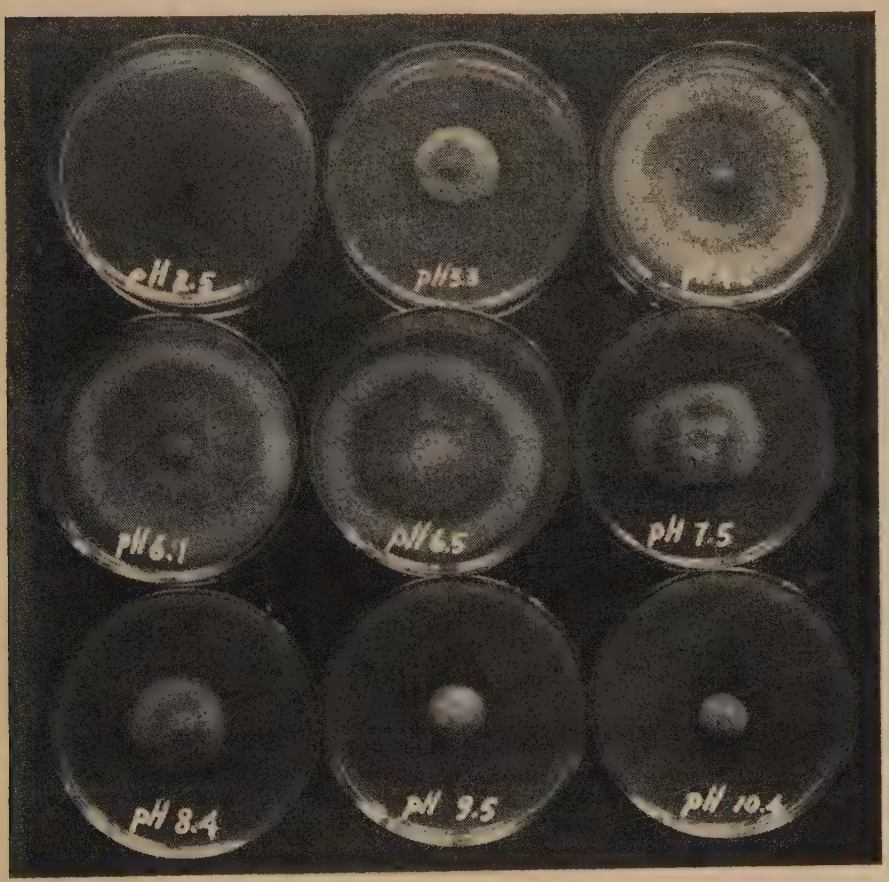

Fig. 3.—Growth and conidial production of *Colletotrichum graminicolum* after 6 days on potato-dextrose agar with pH ranging from 2.5 to 10.4. (*Photograph taken by the Photographic Division*).

made for each pH. All cultures were kept at ordinary room temperature (27° to 28°C). The diameter of mycelial growth was measured and the production of conidia observed daily. The results are presented in table 2.

TABLE 2.—*Growth and conidium production of Colletotrichum graminicolum on potato-dextrose agar of different hydrogen-ion concentrations*

pH OF MEDIA	COMPARATIVE ABUNDANCE OF MYCELIUM	COMPARATIVE ABUNDANCE OF CONIDIA	DIAMETER OF COLONY AFTER 6 DAYS [a]	AVERAGE DAILY GROWTH
1.4	none	none	—	—
2.5	none	none	—	—
3.3	scarce	none	26.6	4.4
4.1	fairly abundant	none	38.8	6.4
6.1	abundant	abundant	51.7	8.6
6.5	very abundant	very abundant	56.2	9.3
7.5	fairly abundant	fairly abundant	36.2	6.0
8.4	scarce	none	23.4	3.9
9.5	scarce	scarce	21.7	4.4
10.4	scarce	scarce	15.6	2.6

[a] Average of three cultures.

Germination of conidia. Spores were taken from infected leaves of corn and mounted in tap water, distilled water, and nutrient broth in Van Tieghem cells and on thin layers of potato-dextrose agar and cornmeal agar on sterilized glass slides. The mounts were placed in Petri dishes lined with moist cotton and were observed hourly for the germination of conidia.

The conidia germinated within 8 to 12 hours on potato-dextrose agar: within 18 to 21 hours, on cornmeal agar and nutrient broth; and 24 to 48 hours, in tap and distilled water. Typical germination was by the production of a polar, hyaline germ tube with appressorium. In some cases, two germ tubes were produced from both ends. Occasionally, a germ tube was produced from the side of the conidium (fig. 2D).

Viability of spores. Diseased corn leaves which had an abundance of spores were incorporated in pots of sterile soil and placed inside the greenhouse. Other pots of sterile soil with infected leaves were exposed to the weather. Diseased leaves were also placed in a closed dry receptacle and kept in the laboratory side by side with potato-dextrose agar slant cultures. At one-month intervals viability tests were carried out. The conidia were suspended in sterile

distilled water in Van Tieghem cells. In the last test, when no germination was observed, conidia were plated on new potato-dextrose agar to further check their viability. Conidia which failed to germinate in distilled water did not germinate on potato-dextrose agar either. The tests showed that the conidia in the dry closed receptacle and in pots placed inside the greenhouse or exposed to the weather remained viable for four months, whereas those from the agar medium retained their viability for more than two months.

TAXONOMY

The fungus that causes anthracnose of corn is listed by Saccardo [5] as *Colletotrichum cereale* Manns and Selby, a synonym of *Colletotrichum graminicolum* (Ces.) Wils. Saccardo describes this fungus as follows: hyphae measure from 2 to 7μ in diameter; conidia, fusoid, curved and hyaline, 18 to 26 $\times$ 3 to 4μ; conidiophores, 2 to 6 $\times$ 1 to 2μ; setae dark brown to black, 6 to 8μ in diameter and 60 to 120μ in length, continuous or 1 to 2 septate. The hyphae of the Philippine fungus are 18.3 to 76.5 $\times$ 3.3 to 6.6μ in size; the conidia, 19.8 to 33.3 $\times$ 6.6 to 9.9μ; conidiophores, 6.6 to 13.3 $\times$ 1.6 to 3.3μ; setae, 36.6 to 166 $\times$ 4.9 to 9.9μ. The discrepancies between the two measurements are attributed by the writer to difference of locality and weather conditions, and the probability that Saccardo's measurements were based on materials produced on cereals other than corn. In the Philippine corn fungus the writer noted variation in the size of acervuli produced on the host tissues. That the fungus causes infection of other cereals and grasses in cross inoculation experiments does not warrant its segregation from *Colletotrichum graminicolum* (Ces.) Wils. Tentatively, therefore, the writer identifies the fungus causing anthracnose of corn in the Philippines with *Colletotrichum graminicolum* (Ces.) Wils.

PATHOGENICITY

Planting seeds in infected soil

On July 8, 1954, corn seeds [6] which had been disinfected with 1:1000 mercuric bichloride and washed with tap water were planted in pots containing a mixture of sterile soil and spores and mycelia

[5] P. A. Saccardo, "Syllogue Fungorum," Ann Arbor, Michigan, Edwards Brothers Inc., Vol. 22, 1884.

[6] Corn seeds were provided by Drs. D. L. Umali and J. L. Brewbaker of the Division of Plant Breeding, Department of Agronomy.

taken from potato-dextrose agar cultures. The pots were placed inside the greenhouse and watered regularly. There was 100 per cent germination and seeds that germinated were observed for the appearance of anthracnose. The seedlings that developed did not have any symptom of infection. After two weeks all 10 pots were placed outside for further observation. After several days spots typical of the disease appeared on the lower leaves. No infection was observed on the control.

Inoculation of the seeds

Concurrently with the foregoing experiment, disinfected corn seeds were immersed in spore suspension of the fungus and planted in 10 pots of sterile soil which were placed and watered in the greenhouse. Five pots planted to corn seeds which had been immersed in sterile water served as control. Most of the seeds germinated and were disease-free. For further observation, the plants were placed outside. Except for insect infestation the plants including the control remained healthy throughout.

Inoculation of the vegetative parts with spore suspension

When two-week-old corn seedlings were sprayed with spore suspension and subjected to the damp chamber for 48 hours, they developed the disease symptoms three days after inoculation. This was confirmed on four-week-old seedlings. On plants in the early silk-and-tasseling stage, the symptoms developed five days after treatment. Disease spots were noted on the leaves and the outer husk of young ears.

Inoculation of leaves with mycelium smear

Five pots of four-week-old corn plants were pricked on the leaves with a dissecting needle and smeared with bits of potato-dextrose agar containing fragments of fungus mycelium. Two pots served as control. All pots were placed in the damp chamber for 48 hours. On the following day disease symptoms were observed on the inoculated plants.

Re-isolation of the fungus

In every inoculation experiment, the causal fungus was re-isolated from the infected corn leaves. In all cases, the morphological and cultural characteristics of the re-isolated fungus were very close to those of *Colletotrichum graminicolum* (Ces.) Wils.

Varietal susceptibility and resistance of corn

The seven commercial varieties of corn inoculated with spore suspension of the fungus did not differ much in their susceptibility to the disease. Varieties P.I. Yellow sweet corn, College Yellow Flint, Cuban Yellow, Bicol White and Nueva Ecija White were easily infected and killed. Although its leaves were killed Catambay's Cuban and I 20 Sib survived.

Host range

The following species of plants belonging to the family Graminae were cross-inoculated to determine whether the pathogen would infect plants other than corn: Bermuda grass, *Cynodon dactylon* (L.) Pers.; Guinea grass, *Panicum maximum* Jacq.; Bungalon grass, *Echinochloa stagnina* Beauv.; crab grass, *Digitaria sanguinalis* (L.) Scop.; Guatemala grass, *Tripsacum laxum* Nash; molasses grass, *Melinis minutiflora* Beauv.; Para grass, *Panicum purpurascens* Raddi; Merker grass, *Pennisetum setosum* (Swartz) L. Rich. These plants were grown in potted soil and inoculated with bits of agar containing fungus mycelium. All other treatments were similar to those employed in previous inoculation experiments. Control plants of each species were provided.

All eight species proved susceptible to the diseases. Lesions produced on Para grass, crab grass, Guinea grass and molasses grass were similar to those produced on corn except that the lesions had yellow borders. The lesions continued to develop on the infected leaves which later shrivelled and died.

LIFE HISTORY OF THE CAUSAL FUNGUS IN RELATION TO PATHOGENESIS

Seasonal occurrence of the disease

Field observation showed that the disease is prevalent during the rainy season. The disease develops most favorably from August to November. During the dry season the plants are also affected by the disease but not as severely.

Methods of penetration

Inoculation experiments have shown that *Colletotrichum graminicolum* is capable of penetrating uninjured leaves directly through the epidermis and through stomatal openings. It is probable that

most infections in the field take place through injuries caused by insects and by man during cultural operations.

Methods of dissemination

By wind. On December 10, 1954, six Petri dishes containing sterile potato-dextrose agar were exposed for 30 minutes in an infected plot of corn. Four Petri dishes were placed about two to three meters from each other at the leeward edge of the infected plot. The remaining two plates were carried around the plot for 10 minutes and then incubated at room temperature (27° to 28°C). After two days various fungi like *Colletotrichum graminicolum* appeared on all the plates. The plates which were carried around the field had the most growth. The other four dishes had approximately the same growth. The results of the experiment indicate that the spores of the fungus can be disseminated by wind.

By insects. Protaetis sp.[7] collected from infected plants in the field were allowed to crawl over sterile plated potato-dextrose agar, incubated at room temperature. After several days colonies of *Colletotrichum graminicolum* developed.

Methods of living over adverse conditions

Infected leaves left in the field after harvest contain abundant spores and mycelium of the fungus. The spores and mycelium within the disintegrating host tissues in the soil may remain dormant until the next corn planting. In the absence of corn in the field the fungus may exist on grasses which serve as sources of inoculum.

Source of inoculum for primary infection

The mycelial fragments and spores from the disintegrating diseased corn trash in the field may be carried by wind and rain splash from the soil to the leaves and cause primary infection.

Source of inoculum for secondary infection

Infection on a new corn may also be initiated by spores from surrounding infected grasses. Diseased plants on which abundant spores may be produced serve as inoculum for secondary infection.

CONTROL MEASURES

Crop rotation. Inasmuch as the fungus can live on decaying plant remains for four months or possibly longer, a one-year crop

[7] Identified by Dr. S. M. Cendaña of the Department of Entomology.

rotation is suggested as a preventive measure against the disease. Dickson [8] stated that since the disease is associated with conditions of depleted or unbalanced soil fertility and continuous grass-cereal culture, planting legumes or cover crops and fertilization of the soil will prevent the occurrence of the disease.

Sanitation. The fungus is a leaf parasite; hence, all infected plants and plant remains should be gathered and burned to eliminate sources of inoculum for the next corn crop.

Cultural practices. Occasional weeding and cultivation of the plants will reduce degree of infection. Grasses which grow along the side and in between the rows of corn plants should be eliminated.

Laboratory test of fungicides. The effectiveness of four commercial fungicides against *Colletotrichum graminicolum* (Ces.) G. W. Wils. was tested. The four fungicides were Bordeaux mixture; Orthocide 50, containing 50 per cent Captan as active ingredient and 50 per cent inert ingredient; Yellow Cuprocide, with 90 per cent Yellow Cuprocide active ingredient and 10 per cent inert ingredient; and Manzate, containing 70 per cent Manganese ethylenebisdithiocarbomate which is equivalent to 14.5 per cent metallic Manganese, and 30 per cent inert ingredient.

Two glass slides were sprayed with each of the fungicides and allowed to dry. Three drops of spore suspension taken from infected corn leaves were placed on the sprayed slides which were placed in Petri dishes lined with moist cotton and incubated at room temperature. After 24 to 48 hours the slides were examined for germinating spores. Control slides were provided.

Bordeaux mixture, prepared at a concentration of 3-3-50, and Manzate, applied at 1½ pounds per 100 gallons, completely prevented germination of the spores. Orthocide 50 applied at 2 pounds per 100 gallons and Yellow Cuprocide applied at 1½ pounds per 100 gallons did not completely inhibit the germination of the conidia of the fuugus for they showed 21.8 and 38.7 per cent germination respectively. Since this experiment was conducted in the laboratory no definite statement can be made as to whether or not these fungicides will give adequate protection to plants in the field. Further studies on the time and frequency of application of fungicides should be conducted in the field.

[8] Dickson, *op. cit.*

CERCOSPORA DISEASE OF OKRA (ABELMOSCHUS ESCULENTUS [L.] MOENCH.) IN THE PHILIPPINES

ROMEO V. ALICBUSAN

WITH TWO TEXT FIGURES

On September 16, 1958, specimens of okra leaves were brought to the Department of Plant Pathology, U.P. College of Agriculture, for diagnosis. Microscopic examinations revealed that the associated organism is a typical species of the genus *Cercospora* (fig. 1).

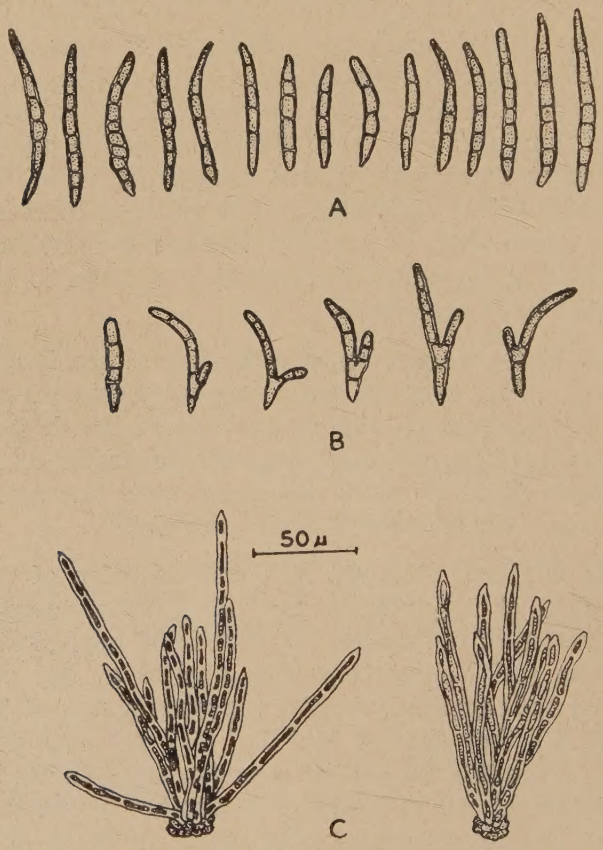

Fig. 1.—Camera lucida drawings of the organism taken from the host. (A) Typical conidia. (B) Branching conidia. (C) Conidiophores. (*Photograph taken by the Photographic Division*).

Observations in the field near the Department of Agronomy, College of Agriculture and Central Experiment Station at Los Baños, showed 100 per cent infection in all six varieties of okra, namely, Sabour Selection; Native Brown; Louisiana Green; Dwarf Green Pod; Perkins Spineless and Clemson Spineless.

The Cercospora disease of okra has been listed by Reinking (1919)[1] who attributed it to *Cercospora hibisci* Tracy and Earle in the Philippines. Chupp (1953)[2] recorded *Cercospora hibisci* Tracy and Earle in 1895 and *C. abelmoschi* Ell. & Evht. from Jamaica in 1893. The reported hosts of these two organisms are *Hibiscus cannabinus* L. and *H. esculentus* L. A study to obtain additional information about the disease is currently in progress in the Department of Plant Pathology.

Symptoms. Parasitism occurs only on fully expanded and mature leaves. Spore production is abundant, sooty to dark olivaceous, from mere specks to large areas on the lower leaf surface (fig. 2).

Fig. 2.—Okra leaves photographed from the nether surface showing different degrees of infection. The striking color of the spots arise from the enormous production of fruiting structures. (*Photograph taken by the Photographic Division*).

[1] Otto A. Reinking, *Philippine Agriculturist*, 8, 38 (1919).

[2] Charles Chupp, "A monograph of the fungus genus Cercospora." Ithaca, New York, 1953, 667 pp.

Few reddish brown spots may develop ranging from small dots to about 10 mm. in diameter. The increase in size of the lesions is restricted by the veins resulting in an irregular shape. Green pods are entirely free from infection but dried pods that remain on the plant also show the presence of the organism.

"The aim of higher education is wisdom. Wisdom is the knowledge of principles and causes. Therefore, metaphysics is the highest wisdom . . ."

—*Hutchins*